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OF THE

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION

BULLETINS 1-11

October, 1889--October, 1916

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North Carolina

Agricultural Experiment Station,

Bulletin No. 67a.

Technical Bulletin No. 1.

I. SEED TESTS.

Publications will be sent to any address upon application.

NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

AND STATE WEATHER SERVICE,

UNDER THE CONTROL OF THE

STATE BOARD OF AGRICULTURE.

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RALEIGH, N. C.

At the time that the Experiment Station Bulletin No. 59 was published, August—September, 1888, a series of examinations of field seeds, mainly grass seed, had been made. The result was startling in the extreme, as the average value was only fifty-six per cent., one hundred per cent. expressing both absolute purity and absolute vitality. The Station refrained from making known the names of dealers who sold these seed, on the broad basis that the retail dealers might not themselves have known the exact character of the seed they had on sale. It was specified, however, that the farmer was the sufferer, and as the prime object of the Experiment Station was for the advancement of the State's agriculture, the improvement of the seed used was of the greatest necessity.

In this present bulletin the work of seed examination has been extended to embrace all the more common garden seed found on sale. The result has been almost as decided as that recorded for field seeds. Although there have been found many varieties of seed, both pure and vital, yet some of the seed on sale show decided evidence of careless handling, in that they were old, musty, and stale. If certain classes of seed are not vital after a year's keeping, then the farmer and seed merchant certainly should become acquainted with the fact. The Station refrains now from publishing, as before, the names of dealers from whom the seed were purchased, for the reason, that possibly those who sold the worthless seed were not aware of the fact, or that they were ignorant of the property that these seed possess of becoming worthless when old. In the future, seed merchants must not expect such forbearance.

A single extract from a paper read by Mr. J. E. Northrup, of Minneapolis, before the Minnesota State Horticultural Society, will show what deception, some seed-houses adopt, and the consequent care which ought to be taken to prevent such practice from becoming wide-spread:

"In walking through a large seed warehouse some time since, I detected the odor of burning brimstone, and my curiosity was aroused as to what part brimstone could play in the fitting of seed for market. Making some pretext for visiting that portion of the building from whence the fumes proceeded, I came to some cucumber seed, which was being Bleached to remove the yellow tint with which age had mellowed it. The tags on the bags indicated that it had been in that building over twenty years, and how much longer no one knows."

In the preparation of seed, then, for the market, adulteration and deception must be guarded against, as much so as in other mercantile professions.

H. B. BATTLE, *Director.*

I.

SEED TESTS.

By GERALD McCARTHY, Botanist.

During the year 1889 the North Carolina Experiment Station has completed analyses and tests of about 1,500 samples of seed. A large portion of these samples were purchased by the Station in North Carolina or sent for examination by farmers; the rest were procured directly from the seedsmen who put them up, and were, in most cases, donated to the Station. It is only fair to the various seedsmen, whose seeds have been tested and reported upon in this Bulletin, to acknowledge that, with the exception of clovers and lucerne seed, most of the different kinds of seeds tested were found true to name and reasonably free from impurities. The low vitality shown by many of the samples—such, for instance, as those contained in the Table II—were due to staleness of the seeds. Stale seeds, unless they have been "doctored," are easily recognizable by an experienced person. They are usually lustreless, which is due to the absorption of the oil, which is always present in the seed-coat of fresh seeds. When stale seeds are found in packets, the containing packets are more or less stained and dirty, and such seeds should never be purchased. Stale lucerne seed has lost its shiny, greenish color, and become dull and brown and more or less withered. Red clover seed also becomes brown with age. In our warm and humid climate, the vitality of seeds, and especially of Northern-grown seeds, deteriorates very rapidly; and seeds of two years old are, as a rule, not worth sowing. Yet, we find that most retail dealers in seeds act in utter disregard of this fact. They seem to think the quality of seeds in packets, like that of meats in cans, is of indefinite duration, and "warranted to keep in any climate." Except clover and grass-seeds, nearly all seeds sold in this market are put up in sealed packets, which are marked with the name of the seedsman who put them up. Some seedsmen place upon their packets the words "warranted" or "guaranteed," but as no details as to the nature of the warrant or the quality guaranteed are given, this must be regarded as a mere bait to catch the credulous. Most seedsmen distinctly disclaim all responsibility for the quality of the seeds in their packets.

The jeweller warrants his watches and rings to be of a certain fineness and weight; the honest dry goods man warrants his wares to be all-wool, or all-linen or as the case may be; and so also with the shoe dealer, grocer and other merchants. There is no real and valid reason why the seed merchant should not also give a real and definite guarantee of the quality of his wares! The necessity of such a guarantee, for the protection of the purchaser, is much more urgent in regard to seeds than in any of the above-mentioned cases. The first cost of seeds is comparatively small, compared with the expense of preparing and fertilizing the ground, and if the seed sown proves to be worthless, or of a different species from that claimed, by the time the fact becomes apparent the season for sowing has passed, and the defrauded purchaser loses, not only all he has invested in seeds, fertilizer, land and labor, but also the value of his prospective crop. In Europe all respectable seedsmen give a positive and definite guarantee of the purity and vitality of their seeds, and there is no reason why American seedsmen should not do the same. So long, however, as seedsmen think they can force their wares, on their own terms, upon the consumer, no advance of this kind need be expected, and just so long will the long-suffering public be annoyed and defrauded by stale and weed-infested seeds. Seedsmen, when asked to give a definite guarantee of their goods, reply that their reputation is the only guarantee they can offer, and that is sufficient for the protection of the purchaser! But this claim is utterly fallacious There are in all trades rascals who, under pretense of honest trading, fleece all whom they can inveigle into their power, and these same rascals may be among the ones who most loudly prate of their reputation. Reputation is a good thing, but business is business, and should be conducted upon business-like principles. The purchaser of seeds may have an unblemished reputation for honesty, but if he were to go into the store of any of these same seedsmen who demand that purchasers shall accept their goods upon the guarantee of their reputation, and offer a piece of unstamped metal in payment for seeds, he would be very likely to discover that the rule of "reputation" does not work both ways. Moreover, nearly all American seedsmen sell the title to their seeds to the retailer, without any real and practicable restriction upon the latter. The retailer naturally thinks he is at liberty to do as he likes with his own seeds, and he generally likes to sell them without inquiring too closely into their quality.

The art of seed-testing upon scientific principles was instituted in 1870, by Dr. Frederick Nobbe, Tharand, Germany, and it has now in European countries reached such perfection as to give entire satisfaction to all concerned. The custom is, in Europe, for seedsmen to sell seeds under a specific guarantee of purity and vitality. The purchaser is at liberty to have the seeds tested by certain public seed-control stations, or by botanists employed by agricultural societies. If the seeds fail to come up to the quality guaranteed, the purchaser has the right to demand a commensurate reduction in price, or he may, if he prefers, return the seeds to the seller and get his money back, the seller being required to pay the cost of freight on the seeds. This fair and business-like arrangement has resulted in driving out of the markets adulterated seeds, while the freedom of commercial seeds from noxious weed-seeds has become greatly increased. Before 1870, when Prof. Nobbe began his useful work, there were several establishments in Europe engaged in the manufacture of bogus clover seeds from quartz rock. The quartz was first crushed and, by means of sieves, graded to the size of different species of clover seeds; it was then colored to imitate the seed which it was meant to adulterate. Prof. Nobbe has shown that in a single year certain English seed firms, and among the most "honorable" in the trade, have purchased tons of this bogus seed. Just how much of this quartz clover reached America, we are not yet able to say, but we have an agent in Europe investigating the matter, and we hope before long to be able to lay the result before the public.

The following form of guarantee is given by a large English seed association, and is, in effect, similar to that given by all European seedsmen:

1. "Our seeds are sold guaranteed pure, clean and of the percentage of vitality named in our catalogue.

2. "This guarantee is subject to the analysis of the botanist of the Royal Agricultural Society.

3. "If the result of the analysis does not confirm the above guarantee, the association will take back the seeds and pay cost of carriage both ways, but seeds must not be sown before making complaint.

4. "The seeds once sown, the responsibility of the association ceases. The result depends upon so many things besides the quality of the seeds that the growth cannot be guaranteed."

This is fair trade and common sense, creditable alike to English seed merchants and English seed purchasers. Where such trade customs prevail there can be no room for "mistakes." Honest and careful seedsmen are protected from the unfair competition of the unscrupulous. The purchaser is assured that he gets just what he wants and pays only for what he gets.

The North Carolina Experiment Station has extensive and very complete arrangements for testing seeds, and its services are at the command of any farmer or seed-user in North Carolina free of charge. Being desirous of introducing a higher grade of seeds into our markets, the Station will publish in an ensuing BULLETIN the names of seedsmen who are willing to give purchasers of their seeds residing in North Carolina a guarantee similar in effect to that quoted above. We invite correspondence on this matter.

The Station has nearly ready for publication, and will shortly publish, the details of a Standard of Quality for the different kinds of seeds more commonly used. In the same BULLETIN we will describe the apparatus and methods used for testing seeds in this Station, and in other American and European Experiment Stations.

It has been thought best to omit, in the present BULLETIN, the names of retail dealers from whom seeds were purchased. Hereafter the names of retailers will be published in connection with the seeds purchased of them, and ose who are found selling poor and worthless seeds may expect no further forbearance on the part of this Station.

TABLE I.—LANDRETH'S SEEDS. BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout appeared.	No. of days before last sprout appeared.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5471	Beet, Bassano	5	18	99	62.	61.38	----------	----------
5480	Cabbage, E. J. Wakefield	3	6	100	92.5	92.5	255	7,229
5506	Cabbage, Large Drumhead	2	6	100	80.	80.	350	9,922
B. 580	Cabbage, L. L. Drumhead	2	10	100	75.5	75.5	318	9.015
5483	Mustard, Brown	1	4	100	84.	84.	380	10,773
5498	Lettuce, E. Curled	3	15	100	73.	73.	1,090	30,901
5493	Spinach, Prickly	4	30	100	70.	70.	92	2.608
5505	Collards, Southern	2	6	100	78.	78.	290	7,521
5507	Mustard, White	1	3	100	100.	100.	178	5,046
5834	Salsify	10	21	95	27.	25.65	----------	----------
5835	Parsnip, H. Crowned	7	18	94	41.	39.33	----------	----------
5836	Carrot, Lt. Orange	3	10	100	67.5	67.50	----------	----------
5838	Collards, Marrow	5	12	100	10.	10.	----------	----------
B. 504	Pepper, Cayenne	7	16	100	75.5	75.5	215	6,095
B. 507	Egg Plant	5	16	100	34.5	34.5	240	6,804
B. 583	Onion, E. Red	2	6	100	92.5	92.5	236	6.690
5866	Tomato, Feejee	3	14	98	58.	56.8	295	8,363
5882	Okra, Dwarf	4	12	99	70.	69.3	17	482

DISCUSSION OF TABLE I.—All the above seeds were put up in packets and sold two for five cents. All except Nos. B. 580, B. 504 and B. 583, were stamped "1889." Those excepted were stamped "1888." These are, with a few exceptions, good seeds.

TABLE II.—ELY'S SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5650	Cabbage, L. L. Drumhead	4	10	100	45.5	45.5	248	7,030
5651	Cabbage, Brunswick Drumhead	3	7	100	9.	9.	279	7,654
5652	Cabbage, L. L. Bergen	7	8	100	4.	4.	--------	--------
5653	Cabbage, L. L. F. Dutch	3	9	100	51.	51.	--------	--------
5670	Cabbage, E. Fr. Oxheart	4	9	100	12.	12.	268	7,597
5671	Cabbage, E. J. Wakefield	3	14	100	58.	58.	262	7,427
5669	Sprouts, Brussels	4	4	100	1.	1.	336	9,525
5837	Parsley, Dbl. Curled	0	0	100	0.	0.	--------	--------
5839	Cucumber, W. Spine	3	6	100	46.3	46.3	--------	--------
5840	Beet, W. Sugar	5	19	100	72.5	72.5	--------	--------
5841	Asparagus, Colossal	0	0	100	0.	0.	--------	--------
B. 585	Onion, Mammoth Silver King	0	0	100	0.	0.	220	6,237
B. 584	Borecole	3	9	100	39.	39.	200	5,670
B. 590	Watermelon, Ironclad	3	9	100	84.	84.	10	283
B. 591	Tomato, K. of Earlies	2	6	100	89.5	89.5	--------	--------

DISCUSSION OF TABLE II.—The above seeds were purchased in retail packets, and were sold at the same price as fresh seed. The discolored packets and the lustreless seeds suggested that they were stale seeds, and the test fully confirmed the suspicion. The retailer subsequently acknowledged that these were old seeds and claims that they were sold to us by mistake. The packets in which these seeds were put up, were marked "Warranted," but neither the grower nor the retailer have offered to refund the money paid by us for the seeds.

TABLE III.—ELY'S SEEDS—BOUGHT IN GREENSBORO, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 505	Egg Plant	4	16	100	31.	31.	240	6,804
B. 511	Tomato, E. Acme	2	9	95	93.	88.3	330	9,355
B. 512	Tomato, Livingston's Perfection	2	18	100	81.	81.	330	9,355
B. 513	Salsify, Mammoth	4	21	100	88.	88.	76	2,154
B. 514	Beet, Egyptian	4	12	94	66.	62.	90	2,551
B. 515	Beet, E. B. Turnip	5	16	100	44.	44.	54	1,531
B. 518	Muskmelon, Golden Gem	4	8	98	82.	80.3	36	1,020
B. 519	Muskmelon, Jenny Lind	4	7	100	98.	98.	37	1,045
B. 520	Muskmelon, Nutmeg	4	8	98	74.	72.5	33	935
B. 521	Squash, E. Bush	3	5	100	86.	86.	12	348
B. 522	Squash, E. Crookneck	3	6	100	92.	92.	12	348
B. 526	Cucumber, E. G. Cluster	2	5	100	86.	86.	40	1,134
B. 527	Cucumber, L. Green	2	6	98	88.	86.2	34	1,163
B. 536	Watermelon, Ice Cream	3	6	100	68.	68.	13	368
B. 537	Watermelon, Mountain Sweet	3	5	96	62.	59.5	7.5	212
B. 538	Watermelon, Scaly Bark	2	4	100	84.	84.	9.5	260
B. 539	Watermelon, L. Rattlesnake	2	4	100	77.5	77.5	9	255
B. 540	Watermelon, Kolb's Gem	2	5	100	92.5	92.5	8	226
B. 550	Cabbage, L. L. Drumhead	1	9	100	78.	78.	----------	----------
B. 551	Cabbage, E. Etampes	2	11	100	62.	62.	----------	----------
B. 552	Cabbage, E. Winningstadt	1	11	100	92.	92.	----------	----------
B. 553	Cabbage, L. L. F. Dutch	1	7	100	82.	82.	----------	----------
B. 554	Cabbage, E. Drumhead	1	10	100	91.	91.	----------	----------
B. 555	Cabbage, E. Dwarf York	1	11	100	87.	87.	----------	----------
B. 582	Cabbage, all seasons	2	8	100	76.	76.	342	9,695

DISCUSSION OF TABLE III.—The packets in which the above seeds were purchased were bright and clean. The quality as will be seen by the column headed "valuation" is, with a few exceptions, good. These were not stale seeds!

TABLE IV.—BURPEE'S SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 573	Cabbage, E. J. Wakefield	3	9	100	34.5	34.5	222	6,293
B. 574	Cabbage, L. L. F. Dutch	3	9	94	32.	32.	248	7,020
B. 575	Cabbage, Henderson's E. Summer	3	9	100	53.	53.	316	8,958
B. 576	Cabbage, E. Jersey Wakefield	3	9	66	28.5	28.5	------	--------
B. 577	Cabbage, E. Cannon Ball	9	9	100	12.	12.	426	12,077
B. 578	Cabbage, Fottler's Brunswick	6	9	100	5.5	5.5	280	7,428
B. 579	Cabbage, Surehead	5	9	100	33.	33.	280	7,428
B. 580	Cabbage, Short-stem Drumhead	3	9	100	57.	57.	350	10,026
B. 581	Cabbage, E. Deephead	4	10	100	44.	44.	336	9,525
B. 587	Squash, R. China	3	9	100	39.5	39.5	9	255
B. 588	Cucumber, Giant Pera	3	9	100	94.	94.	25	709
B. 589	Muskmelon, Bay View	2	9	99	75.5	74.7	31	879

DISCUSSION OF TABLE IV.—The above seeds were put up in packets and were sold at the price of fresh seeds of the same kind. The packets were very much discolored and showed the effects of much handling. The seeds lacked lustre and No. B. 576 was badly weevil eaten. Messrs. Burpee inform us that they have sold no seeds to the firm we purchased these from since February, 1886. Hence, the above seeds were at the very latest, of the growth of 1885, or four years old. It must be remembered that a laboratory test is always more favorable than a field test would be, and it is most probable that not one seed out of one hundred of these cabbage seeds would produce a good plant.

TABLE V.—CROSSMAN BROS. SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5475	Beet, Bassano	6	18	99	78.	77.2		
5494	Radish, E. Scarlet	2	5	100	39.5	39.5	120	3.402
5499	Lettuce, E. Curled	3	8	100	60.5	60.5	925	26,253
5484	Onion, White	5	13	100	17.	17.	290	8.221
5474	Cabbage, E. Winningstadt	4	6	97	26.	25.2	295	8,263
5476	Cabbage, E. F. Dutch	2	6	100	83.	83.	225	6.378
5488	Cucumber, E. G. Cluster	3	10	100	60.	60.	38	1,077
5482	Mustard, S. Giant	1	5	100	92.	92.	775	21,971
5491	Spinach, Summer	2	11	100	18.	18.	105	2,976
5500	Tomato, Acme	2	8	100	91.	91.	362	10,252
5858	Corn, Sugar	3	6	100	74.	74.	5.75	163
5859	Corn, Stowell's Evergreen	3	6	100	50.	50.	5.25	148

DISCUSSION OF TABLE V.—The above seeds were purchased in retail packets costing from five to fifteen cents each and were advertised as "New Crop Seeds." The packets were rather dirty and the seed looked stale. The low vitality of the corn seed showed conclusively that these were at least three years old.

TABLE VI.—FERRY'S SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5795	Collards. Georgia	2	9	100	82.5	82.5	256	7,257
5796	Cabbage, E. Dwf. F. Dutch	2	6	100	93.	93.	244	6,917
5797	Cabbage, Pr. F. Dutch	1	6	100	90.	90.	250	7,087
5798	Cabbage, E. Drumhead	1	9	100	75.	75.	254	7,202
5799	Cabbage. E. J. Wakefield	1	6	100	75.5	75.5	272	7,711
5817	Onion, Silverskin	4	11	100	76.	76.	292	8,278
5818	Radish, E. Scarlet	1	4	98	59.5	58.3	106	3.005
5819	Spinach, Prickly Seed	4	13	97	34.5	33.4	99	2,806
5842	Beet, E. Bassano	4	9	96	36.	34.5	46	1,304
5843	Okra, Dwarf White	4	30	100	80.	80.	19	359
5844	Lettuce, Simpson's Curled	2	14	100	49.	49.	640	18,144
5845	Turnip, Purple W. Tip	1	4	100	90.5	90.5	600	17,010
5846	Onion. W. Portugal	2	7	100	61.5	61.5	300	8,505
5847	Salsify	4	20	100	53.	53.	103	2,920
5848	Carrot, L. Orange	3	9	96	65.	62.4	640	18,144
B. 503	Celery, Golden Heart	0	0	100	0.	0.	2,140	60,669
B. 506	Egg Plant	4	9	100	21.5	21.5	330	9,255

DISCUSSION OF TABLE VI.—The above seeds were purchased in retail packets and cost five cents each. The packets were fresh and clean. The quality with a few exceptions is good.

TABLE VII.—FERRY'S SEEDS—BOUGHT IN GREENSBORO, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 509	Celery, Seymour's Golden	7	28	100	38	38.	2,700	76,545
B. 561	Cabbage, Pr. L. F. Dutch	2	8	100	83	83.	300	8,505
B. 562	Cabbage, E. Winningstadt	2	9	100	76	76.	316	8,958
B. 563	Cabbage, Stone Mason Drumhead	2	7	100	76	76.	288	8,164
B. 564	Cabbage, L. Drumhead	3	9	100	75	75.	260	7,371
B. 565	Cabbage, L. E. York	3	8	100	32	32.	280	7,938
B. 566	Cabbage, E. J. Wakefield	2	5	100	74	74.	296	8,391
B. 530	Radish, L. B. Spanish	2	7	99	70	69.3	118	3,345
B. 528	Cucumber, E. Russian	2	5	98	80	78.4	43	1,219
5867	Tomato, L. Perfection	2	10	96	87	83.3	350	9,922
5869	Tomato, Canada Victor	3	15	99	72	71.2	420	11,909
5881	Squash, B. Scallop	2	7	99	86	85.1	11	312
5883	Cucumber, E. W. Spine	2	4	99	82	81.1	41	1,162

DISCUSSION OF TABLE VII.—The above seeds were purchased in retail packets and the packets were fresh and clean.

TABLE VIII.—Cleveland's (?) Seeds—Bought in Raleigh, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5470	Beet, Egyptian	5	11	100	80.5	80.5	----------	----------
5473	Turnip, E. White	3	13	100	74.5	74.5	720	20,412
5478	Cabbage, E. J. Wakefield	3	8	100	26.5	26.5	----------	----------
5496	Radish, E. White	1	6	100	82.5	82.5	114	3,232
5502	Tomato, Mikado	2	8	100	92.5	92.5	342	9,695
5503	Collards, Southern	2	6	100	80.5	80.5	295	8,363
5497	Lettuce, Seymour's E. C	4	11	100	73.	73.	----------	----------
B. 510	Lettuce, Prize Head	2	7	100	86.	86.	650	18,427
B. 502	Bean, Large Lima	2	6	100	96.6	96.6	----------	----------
5875	Muskmelon, Cantaloupe	2	8	94	99.	93.	42	1,190
5876	Muskmelon, Nutmeg	3	7	99	97.	96.	29	822
5877	Muskmelon, Hackensack	2	6	99	99.	98.	42	1,190
5878	Pumpkin, Cheese	2	4	98	71.	69.5	----------	----------

Discussion of Table VIII.—The above seeds were in retail packets and the packets were somewhat dirty. The name of the growers was not printed on the packets, that of the retailers being put in evidently to order. The style of packet and the way of doing business are those of Cleveland & Co., of New York, and presumably these seeds were put up by them. The quality of these seeds is above the average.

TABLE IX.—CLEVELAND'S (?) SEEDS—BOUGHT IN GREENSBORO, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 516	Muskmelon, G. Nutmeg	4	6	100	100	100	33	935
B. 517	Muskmelon, Hackensack	4	7	100	88.	88.	42	1,190
B. 523	Cucumber, W. Spine	3	5	100	36.	36.	43	1,219
B. 524	Cucumber, Improved L. G	2	6	100	80.	80.	36	1,020
B. 525	Cucumber, E. Cluster	2	5	100	90.	90.	39	1,005
B. 531	Radish, E. Short Top	2	9	100	81.	81.	78	2,211
B. 532	Watermelon, Ironclad	2	6	100	84.	84.	7.5	212
B. 533	Watermelon, Peerless	2	6	100	92.	92.	10	283
B. 534	Watermelon, Rattlesnake	2	6	100	76.	76.	9	255
B. 535	Watermelon. Mountain Sweet	2	6	100	94.	94.	11	311
B. 541	Pepper, Bullnose	3	13	95	61.	58.	152	4,359
B. 544	Tomato, Liv's. Beauty	2	5	100	92.	92.	312	8,845
B. 545	Tomato, Acme	2	5	100	85.	85.	308	8,731
B. 546	Tomato. Early Acme	3	6	100	92.	92.	322	9,184
B. 548	Onion, W. Silverskin	2	14	100	60.5	60.5	--------	--------
B. 549	Onion. Weathersf. Red	3	9	100	52.	52.	--------	--------
B. 557	Cabbage, L. F. Dutch	3	9	100	88.	88.	360	10,206
B. 558	Cabbage, Marblehead Mammoth	3	10	100	61.	61.	280	7,938
B. 559	Cabbage, L. L. Drumhead	3	9	100	62.	62.	312	8,845
B. 560	Cabbage, E. Etampes	3	10	100	75.5	75.5	288	8,165

DISCUSSION OF TABLE IX.—The above seeds were in retail packets and the packets were fresh and clean. The name of the growers was omitted and replaced on the packets by that of the retailers. Cleveland's seeds presumably. Quality above the average.

TABLE X.—BUIST'S SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5472	Beet, Turnip	7	15	99	53.	52.	61	1,729
5477	Cabbage, E. F. Dutch	2	6	100	84.	84.	124	3,515
5479	Cabbage, E. J. Wakefield	3	6	100	74.	74.	275	7,796
5481	Cabbage, N. C. Buncombe	3	6	100	79.	79.	295	8,363
5485	Onion, Silverskin	3	9	100	89.	89.	295	8,363
5486	Onion, Y. Danvers	3	10	100	66.5	66.5	280	7,938
5487	Celery, Sandr. White	8	25	100	80.5	80.5	2,500	70,875
5489	Cucumber, E. Russian	6	17	99	58.5	57.9	....	....
5492	Spinach, Curled	3	7	100	85.5	85.5	153	4,394
5495	Radish, Fr. Breakfast	2	7	100	84.	84.	124	3,515
B. 529	Radish, B. Spanish	2	6	96	90.	86.4	....	....
B. 571	Sage	3	14	100	50.	50.	....	....
B. 572	Thyme	3	7	100	9.5	9.5	....	....
B. 570	Kale, Scotch	1	3	100	96.	96.	....	....
B. 569	Kohl-Rabi	2	8	100	80.	80.	....	....
B. 568	Carrot, E. S. Shorthorn	3	17	100	47.	47.	....	....
B. 567	Leek, Mammoth	2	17	96	51.	49.	....	....
B. 543	Pepper, Red Cherry	3	12	100	82.	82.	170	4,819
B. 542	Pepper, B. Spanish	3	12	98	70.	69.	136	3,855
B. 508	Egg Plant	5	18	100	59.	59.	240	6,804

DISCUSSION OF TABLE X.—The above seeds were in retail packets and the packets were clean and fresh. Quality fair. Such seeds as Egg plant, Pepper, Thyme, &c., never give a high percentage of vitality.

TABLE XI.—BUIST'S SEEDS—BOUGHT IN RALEIGH, N. C.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5854	Corn, Chester Co. Mammoth	2	6	100	80.5	80.5	2.6	75
5855	Corn, Golden Dent	2	6	100	98.	98.	2.5	72
5856	Corn, Adam's Sweet	3	6	100	68.	68.	11.5	127
5857	Corn, Good Seed	3	5	100	94.	94.	3.75	93
5860	Bean, China Red-eye	3	6	100	100.	100.	1.75	50
5861	Bean, Sewee	3	6	100	84.	84.	2.	56
5862	Bean, Black Wax	3	6	100	92.	92.	2.75	78
5863	Bean, E. Valentine	3	6	100	98.	98.	2.5	71
5864	Bean, E. Dwarf W. Wax	3	6	100	90.	90.	2.75	78
5865	Bean, E. Golden Wax	3	6	100	98.	98.	2.5	71
5870	Bean, E. Mowhawk	2	4	100	92.	92.	2.	56
5871	Pea, Extra Early	2	4	100	98.	98.	4.75	134
5872	Pea, Little Gem	2	5	100	96.	96.	4.25	120
5873	Pea, Thom. Thumb	2	4	100	100.	100.	4.	113

DISCUSSION OF TABLE XI.—The above seeds were in bulk and were purchased of a different firm from those on preceding table. Quality good.

TABLE XII.—LANDRETH'S SEEDS—DIRECT FROM THE GROWER.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity. per cent.	Vitality. per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5804	Cabbage, L. L. Drumhead	2	5	98	89.5	87.7	241	6,832
5805	Cabbage, L. L. Mountain	2	11	100	90.5	90.5	258	7,914
5806	Cabbage, Mammoth Bergen	2	11	100	95.5	95.5	316	8,958
5807	Cabbage, Ulm Savoy	3	7	99	51.5	50.9	304	8,618
5808	Cabbage, Green Glazed	2	10	100	73.	73.	388	11,000
5809	Kale, T. Scotch	2	4	100	99.5	99.5	434	12,304
5810	Collards, Southern	2	12	100	89.	89.	296	8,391
5811	Collards, Marrow	3	13	100	44.5	44.5	334	9,469
5812	Brocoli, L. E. White	3	11	100	62.	62.	418	11,850
5813	Sprouts, Brussels	2	10	100	88.5	88.5	284	8,051

DISCUSSION OF TABLE XII.—These seeds were purchased by the Station at the catalogue price and were sent from Philadelphia by mail, in half ounce packets.

TABLE XIII.—Henderson's Seeds—Direct from the Grower.

Station Number	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
5681	Bermuda Grass	10	30	100	52.	52.	4,140	117,369
5814	Cauliflower, Veitche's	2	7	100	88.5	88.5	462	13,099
5815	Cauliflower, Lenormand's	2	11	100	92.5	92.5	306	8,675
5816	Cauliflower, Algiers	2	11	100	77.5	77.5	360	10,206
5820	Cabbage, Marblehead	2	7	100	90.5	90.5	348	9,866
5821	Cabbage, Filderkraut	2	9	100	88.5	88.5	320	9,072
5822	Cabbage, Sel. L. Flat Dutch	2	9	100	69.	69.	328	6,464
5823	Cabbage, Autumn King	2	5	100	97.	97.	190	5.838
5824	Cabbage, Green-glazed	2	5	100	98.5	98.5	260	7,371
5825	Cabbage, Excel. Flat Dutch	2	4	100	87.5	87.5	300	8.505
5826	Cabbage, M'mth Rock Red	2	6	100	85.	85.	284	8,051
5827	Cabbage, Am. Drumhead Savoy	2	9	100	92.	92.	370	10.489
5828	Cabbage, Henderson's Succession	2	4	100	96.	96.	268	7,598
5829	Cabbage, Fottler's Brunsw	2	5	100	90.	90.	287	8,126
B. 592	Pyrethrum Roseum	4	28	100	67.	67.	360	10,206
B. 593	Johnson Grass	8	11	94	2.	1.88	280	7,938
B. 594	Japan Clover	3	9	100	76.	76.	820	23.247
B. 595	Pearl Millet	3	5	100	68.	68.	210	5.953
B. 596	Louisiana Grass	4	9	80	3.5	3.	940	26,649
B. 597	Randall Grass	3	14	98	44.	43.	720	20,412
B. 678	Texas Blue Grass	7	24	100	5.	5.	----------	----------

Discussion of Table XIII.—The above samples were received direct from Messrs. Henderson, and. with a few exceptions, sprouted very satisfactorily. Nos. B. 593, and B. 678, are grasses which never give a high per centage of sprouted seeds. Of these two samples, B. 593 was kept in apparatus for 45 days during July and August, with temperature ranging from 85° to 95°, plenty of moisture constantly present, yet at the end of 45 days, 90 per cent. of the seeds were hard. The seeds of this grass are usually harvested before they are fully ripe, as when ripe they shatter out very readily. This is probably the cause of the unsatisfactory test. No. B. 596 all molded after the 12th day. No. B. 678 were kept in the apparatus for 45 days, but gave no sprouts after the 24th day, and all were moldy at the end of test. The genus *Poa* seems to produce seed of lower vitality than any other cultivated grass.

TABLE XIV.—NUNGESSER'S SEEDS—DIRECT FROM THE GROWER.

Station Number	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 790	Vetch	1	6	96	95.5	91.6	27	765
B. 791	Sanfoin	4	12	97	51.	49.5	48	1.361
B. 792	Serradella	5	12	98	30.	29.	366	10.206
B. 793	Lucerne	1	27	100	80.	80.	480	13,608
B 794	Alsike Clover	1	12	98	85.	83.	1,830	51,880
B. 795	Red Clover	1	29	100	89.	89.	722	20,468
B. 796	Crimson Clover	1	8	98	96.5	94.6	310	8,788
B. 797	Johnson Grass	6	20	90	23.	21.7	260	7,371
B. 798	Perennial Rye Grass	4	16	99	91.	90.8	610	17,293
B. 799	Italian Rye Grass	5	11	98	86.5	84.8	500	14,175
B. 800	Tall Oat Grass	5	16	98	84.	82.	410	11,623
B. 801	Orchard Grass	6	28	97	73.	71.7	1.200	34,020
B. 802	Meadow Fescue	5	18	99	71.	70.	610	17,293
B. 803	Perr. S. Vernal Grass	7	35	90	25.	22.5	2,200	62.370
B. 804	Timothy Grass	3	8	100	94.	94.	2,810	79.663
B. 806	Red Top Grass	3	11	96	53.	51.	10,600	300,510

DISCUSSION OF TABLE XIV.—The above samples of seeds were sent to the Station by Henry Nungesser, New York. The vitality is, in all cases, except B. 806, very high for the species given. The purity, also, is much above the average for grass and clover seeds.

TABLE XV.—LECOQ'S SEEDS. DIRECT FROM GROWER, DARMSTADT, GERMANY.

Station Number	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality. per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 680	Kentucky Blue Grass	0	0	99	0.	0.	4,560	129,276
B. 683	Wood Meadow Grass	4	24	98	17.	16.6	5,040	142.844
B. 684	Water Meadow Grass	0	0	96	0.	0.	3,100	87,885
B. 685	Annual Sweet Vernal Grass	10	30	98	8.	7.8	1,700	48.195
B. 686	Tall Oat Grass	3	30	99	63.	62.3	330	9,355
B. 687	Fiorin	2	9	98	34.	33.6	10,500	297,695
B. 688	Yellow Oat Grass	4	24	95	27.	26.	4,475	126,866
B. 689	Meadow Fox Tail	3	24	98	73.	71.5	1,120	31,752
B. 690	Meadow Fox Tail	3	18	99	69.	68.3	1,200	34,020
B. 691	Narrow-leaved Fescue	5	14	99	50.	49.5	4,900	138,915
B. 692	Sheep's Fescue	3	21	99	60.	59.5	1,420	40.275
B. 693	Hard Fescue	3	19	98	66.	64.7	1,380	37,124
B. 694	Red Fescue	7	19	99	17.	16.8	2,270	64,354
B. 695	Meadow Fescue	2	22	98	87.	85.3	570	16,159
B. 696	Meadow Fescue	3	15	98	90.	88.2	610	17,293
B. 697	Various-leaved Fescue	7	15	94	13.	12.2	1,570	55.849
B. 698	Randall Grass	3	11	99	72.	71.2	640	18.144
B. 699	Randall Grass	3	18	99	60.	59.5	740	20,979
B. 700	Orchard Grass	3	9	90	82.	74.	1,590	45,076
B. 701	English Rye Grass	3	9	99	82.	81.	500	14,175
B. 702	Italian Rye Grass	2	14	98	89.	87.2	590	16,726
B. 703	Crested Dog's Tail (1887 growth)	7	19	99	39.	38.6	2,600	73,710
B. 704	Crested Dog's Tail (1888 growth)	5	18	99	49.	48.5	2,560	72.576
B. 705	Velvet Grass (Holcus)	4	15	94	24.	23.	2,920	82.782
B. 706	Reed Canary Grass	4	15	100	13.	13.	1,900	53,863
B. 707	Yarrow (Achillea)	2	21	99	60.	59.4	9,280	263,088

DISCUSSION OF TABLE XV.—The above samples of seeds were received direct from LeCoq & Co., Darmstadt, Germany. The purity percentage is, in every case, very high for seeds of this kind, but the vitality percentage is rather low in many cases. These seeds were sent to us by mail, and it may be were injured in transportation.

TABLE XVI.—JAMES HUNTER'S SEEDS, CHESTER, ENGLAND. DIRECT FROM GROWER.

Station Number	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 767	Alsike Clover	2	8	99	89.	88.	1,675	47,486
B. 768	Red Clover	2	8	95	80.	76.	500	14.175
B. 769	Late Red Clover	2	8	99	90.	89.	590	16,726
B. 770	Tall Fescue	6	16	98	83.5	72.	594	16,840
B. 771	Meadow Fescue	6	16	100	76.	76.	556	15,763
B. 772	Hard Fescue	6	15	100	68.5	68.5	1,165	33,027
B. 773	Orchard Grass	12	23	100	82.	82.	885	25,393
B. 774	Meadow Foxtail	6	18	98	42.	41.	1,155	32,744
B. 775	Timothy	8	22	99	87.	86.	2,700	76,545
B. 776	Kentucky Blue Grass	12	12	100	1.	1.	4,325	122,613
B. 777	Crested Dog's Tail	10	36	100	90.	90.	1.890	81,931
B. 778	Perennial Rye Grass	2	16	100	89.	89.	472	13,381
B. 780	Italian Rye Grass	4	16	100	81.	81.	490	13,891

DISCUSSION OF TABLE XVI.—The above samples of seeds were received directly from Mr. Hunter, Chester, England, by mail. Both the purity and vitality percentages are unusually high for seeds of these kinds. The *Poas*, as usual, give the lowest percentage of vitality.

TABLE XVII.—U. S. AGRICULTURAL DEPARTMENT SEEDS.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 599	Serradella	7	13	97	4.	3.9	310	8,788
B. 600	Spurry, Giant	2	17	100	62.5	62.5	950	26,932
B. 601	Sulla	8	8	100	1.	1.	90	2.551
B. 602	Pea, Small	3	6	100	100.	100.	3	85
B. 603	Bean. Horse	5	11	100	66.	66.	3	85
B. 604	Clover, Honey	2	11	98	16.5	16.	415	11,765
B. 605	Lathyrus Hirsutus	4	18	100	65.	65.	37	948
B. 606	Vicia Sativa	2	4	97	71.	69.	22	623
B. 607	Pumpkin, Student	3	5	70	87.	61.	6	170
B. 608	Muskmelon, E. Gem	3	5	100	10.	10.	35	992
B. 609	Squash, N. E. Gem	5	12	100	36.	36.	15	425
B. 610	Watermelon, Perfection	4	6	100	82.	82.	11	111
B. 611	Cucumber, Nichols'	1	5	98	84.	82.	38	1,077
B. 612	Parsnip, Student	5	15	98	46.	45.	860	24,386
B. 613	Parsley, Moss-curled	7	17	100	32.5	32.5	640	18,144
B. 614	Carrot, Golden Orange	4	15	100	73.	73.	----------	----------
B. 615	Sanfoin	4	9	92	38.	33.	46	1,304
B. 616	Salsify, Mammoth	6	14	100	39.	39.	----------	----------
B. 617	Spinach, B. Savoy	3	9	100	18.	18.	119	3,373
B. 618	Okra, N. W. Velvet	2	12	100	63.	63.	17	483
B. 619	Lettuce, Deacon	4	7	100	3.	3.	830	23,530
B. 622	Beet. Edmond's Turnip	3	9	100	72.	72.	60	1,701
B. 623	Beet, Sugar	3	9	100	49.	49.	59	----------
B. 624	Rutabaga, American	1	8	100	98.	98.	----------	----------
B. 625	Turnip, Purple-top	1	8	100	93.	93.	----------	----------
B. 626	Radish, Scarlet Globe	1	5	100	50.	50.	----------	----------
B. 627	Collards. Imp. Georgia	2	8	100	61.	61.	----------	----------
B. 628	Cauliflower, Eclipse	2	8	100	64.	64.	----------	----------
B. 629	Kale, Dwarf German	1	6	100	84.	84.	----------	----------
B. 630	Cabbage, Surehead	2	8	100	80.	80.	----------	----------
B. 631	Cotton, Ellsworth	3	7	100	80.	80.	11	311

TABLE XVII.—U. S. AGRICULTURAL DEPARTMENT SEEDS—*Continued.*

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity per cent.	Vitality per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 632	Cotton, Ellsworth	3	8	100	74.	74.	11	311
B. 633	Cotton, Champion Cluster	3	8	100	89.	89.	8.5	240
B. 634	Cotton, Welborn's Pet	3	7	100	81.	81.	9.5	269
B. 635	Cotton, Wimberly's Imported	3	7	100	78.	78.	10.5	297
B. 636	Cotton, Ferrell's Prolific	4	7	95	30.	28.5	10.5	297
B. 637	Cotton, Truitt's Imported	4	11	100	84.	84.	8	226
B. 638	Sorghum, No. 53	2	5	100	81.	81.	45	1,275
B. 639	Sorghum, No. 26	2	5	100	82.	82.	55	1,559
B. 640	Sorghum, No. 57	2	5	100	83.	83.	50	1,417
B. 641	Sorghum, No. 51	2	5	100	90.	90.	48	1,361
B. 642	Sorghum, No. 68	2	5	100	90.	90.	45	1,275
B. 643	Sorghum, Unnamed (Ga)	2	5	100	72.	72.	45	1,275
B. 644	Sorghum, No. 15	2	5	100	89.	89.	50	1,417
B. 645	Sorghum, Unnamed (Texas)	2	5	97	66.	64.	44	1,247
B. 646	Sorghum, White India	0	0	100	0.	0.	48	1,361
B. 647	Sorghum, E. Tennessee	2	7	100	79.	79.	41	1,162
B. 648	Sorghum, Whitting's Early	2	7	100	91.	91.	49	1,389
B. 649	Sorghum, Price's N. Hybrid	2	7	100	87.	87.	56	1,587
B. 650	Sorghum, Swain's Golden	2	3	100	97.	97.	58	1,644
B. 651	Sorghum, Chinese	3	7	100	90.	90.	39	1,105
B. 652	Sorghum, Folger's Early	2	3	100	98.	98.	47	1,342
B. 653	Sorghum, Ennyama	3	3	100	2.	2.	48	1,361
B. 654	Sorghum, No. 46	2	5	100	77.	77.	48	1,361
B. 655	Sorghum, Gooseneck	5	7	100	11.	11.	48	1,361
B. 656	Sorghum, Waubansee	2	6	100	93.	93.	38	1,077
B. 657	Sorghum, E. Amber	1	4	100	90.	90.	51	1,446
B. 658	Sorghum, New Sugar Cane	2	6	100	91.	91.	47	1,332
B. 659	Sorghum, Planter's Friend	2	6	100	74.	74.	48	1,361
B. 660	Sorghum, Saccharatum	2	8	100	95.	95.	40	1,134
B. 661	Sorghum, Improved Orange	2	5	100	65.	65.	46	1,304
B. 662	Sorghum, Early Orange							

B. 663	Sorghum, Late Orange	2	7	92	11.	10.	58	1,644
B. 664	Corn, White Field	2	5	100	98.	98.		
B. 665	Corn, Yellow Field	2	5	100	98.	98.		
B. 666	Corn, Chicago Sweet	2	5	100	93.	93.		
B. 667	Bean, L. Y. Six Weeks	3	7	100	92.	92.		
B. 668	Corn, Ensilage	2	5	100	70.	70.		
B. 669	Corn, Red Kaffir	2	7	100	92.	92.		
B. 670	Corn, White Kaffir	2	6	100	76.	76.		
B. 671	Corn, Brazil Flour	2	5	100	85.	85.		
B. 672	Pea, R. N. Yorker	4	9	100	90.	90.		
B. 673	Teosinte	2	16	100	67.	67.		
B. 674	Rye Grass, Italian	2	10	96	61.	65.		
B. 675	Blue Grass, Kentucky	6	11	94	3.	4.6		
B. 676	Blue Grass, Texas	0	0	100	0.	0.		
B. 677	Blue Grass, English	2	10	100	86.	86.		
B. 781	Rescue Grass	4	22	95	67.5	64.	70	2,750
B. 782	Mangel Wurtzel	3	30	95	70.0	66.5	58	1,644
B. 783	Sunflower, Mammoth Russ	2	5	95	74.	75.	18	510
B. 784	Asparagus, Hub	8	27	100	77.	77.	47	1,332
B. 785	Onion, Soutpt. Yellow Globe	4	11	100	25.	22.	304	8,618
B. 786	Ramie	5	22	100	45.	45.	19,620	556.276
B. 787	Honey Plant, Chapman's	2	9	100	72.	72.	58	1,644

Discussion of Table XVII.—The above samples of seeds were received directly from the U. S. Department of Agriculture. The purity was, in most cases, equal to the best quality of similar seeds put up by seedsmen. The low vitality of several of the sorghum samples was due to weevil-eaten seed.

TABLE XVIII.—MISCELLANEOUS.

Stat'n Number.	Name.	Source.	No. of days before first sprout.	No. of days before last sprout.	Purity, per ct.	Vitality per ct.	Valuation, per ct.	No. of seeds in one gram.	No. of seeds in one ounce.
5531	Lucerne	Purchased in Raleigh, N. C.	2	10	98	68.	66.6	540	18,144
5332	Lucerne	Purchased in Raleigh, N. C.	1	5	90	74.	69.6	460	13,041
B. 709	Lucerne	Purchased in Raleigh, N. C.	3	7	96	49.	41.		
B. 717	Lucerne	Wood & Son, Richmond, Va.	7	18	98	80.	78.		
5530	Red Clover	Purchased in Raleigh, N. C.	2	6	94	90.	84.	680	19,276
5679	Red Clover	Purchased in Raleigh, N. C.	2	4	95	88.	83.	730	20,695
B. 705	Red Clover	Purchased in Raleigh, N. C.	3	6	94	44.	41.		
B. 706	Red Clover	Purchased in Raleigh, N. C.	2	6	90	95.	85.5		
B. 707	Red Clover	F. M. Scroggs, Morganton, N.C.	2	6	75	88.	66.		
B. 708	Red Clover	Miller & Son, Lynchburg, Va.	2	4	96	85.	81.6		
B. 715	Red Clover	Wood & Son, Richmond, Va.	2	6	95	83.	79.		
B. 711	Crimson Clover	Purchased in Raleigh, N, C.	2	5	95	90.	85.5		
5458	Kentucky Blue Grass	Purchased in Raleigh, N. C.	14	24	98	19.	18.6	6,540	182,857
5831	Kentucky Blue Grass	Purchased in Raleigh, N. C.	7	25	98	5.	4.9	5,190	147,136
5680	Johnson Grass	H. Post, Alabama	7	21	95	14.	13.3	390	11,156
B. 712	Tall Oat Grass	Miller & Son, Lynchburg, Va.	2	10	99	52.	51.5		
B. 713	Randall Grass	Miller & Son, Lynchburg, Va.	2	12	99	50.5	50.		
B. 500	Orchard Grass	Wood & Son, Richmond, Va.	7	18	98	77.5	76.		
B. 501	Orchard Grass	Wood & Son, Richmond, Va.	7	21	94	55.	52.		
5849	Corn, Stowell's Eng.	Purchased in Raleigh, N. C.	3	8	100	100	100	5.5	157
5350	Corn, Black Mexican	Purchased in Raleigh, N. C.	4	9	100	94.	94.	3.5	82
5851	Corn, Adams' Early	Purchased in Raleigh, N. C.	4	9	100	86.	86.	4.5	127
5852	Corn, Golden Dent	Purchased in Raleigh, N. C.	5	10	100	80.	80.	2.5	61
5584	Pyrethrum Roseum	Jas. Vick, Rochester, N. Y.	4	17	99	52.	51.	340	9,639
5534	Onion, Bermuda W.	Wood & Son, Richmond, Va.	3	9	98	69.	67.6		
5535	Onion, Southp't Globe	Wood & Son, Richmond, Va.	2	9	100	88.	88.	290	821
5800	Cabbage, All Seasons	Northrup & Co., Minn.	2	4	97	93.	91.7	256	7,257
5801	Cabbage, Gold. Savoy	Northrup & Co., Minn.	2	7	100	87.	87.	283	8,023

5802	Cabbage, Stone Mason	Northrup & Co., Minn	2	9	96	71.	68.	284	8,051
5803	Cabbage, Surehead	Northrup & Co., Minn	2	9	98	97.	95.	228	6,964
5853	Rutabaga	D. Moore, Maine	2	5	100	94.	94.	334	9,469
B. 598	Rutabaga, Elephant	Carter & Co., London	1	4	100	99.	90.	336	9,525

Discussion of Table XVIII.—Of above samples, No. 5530 was found to contain five per cent. of broken quartz grains. These grains showed, under the microscope, a clean, ragged fracture, and were not grains of sand, but evidently the harvest of some convenient rock pile or mine. This sample was taken from a lot of seed said to have been grown in Davidson County, N. C. Nos. B. 708 and B. 709 contained nearly two per cent. of dodder—enough to poison a whole field. Nos. 5458 and 5831 gave only nineteen per cent. and five per cent. respectively of sprouted seeds. though kept in the apparatus for sixty days. Eventually they molded and were thrown out. It is the custom of botanists to count one-third of all the seeds remaining hard at the end of fifteen days as capable of sprouting, but in the case of these samples, such an allowance would not be correct, as no sprouts were obtained after the twenty-fifth day. No. 5680 gave no sprouts after the twenty-first day, though kept in apparatus for forty-five days, with temperature at 85° to 95°, and ample moisture. Eighty-six per cent. were sound at end of forty-five days.

TABLE XIX.—SEEDS GROWN IN NORTH CAROLINA IN 1889, AND EXHIBITED AT STATE FAIR.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Purity, per cent.	Vitality, per cent.	Valuation per cent.	No. of seeds in one gram.	No. of seeds in one ounce.
B. 809	Millet, Golden	2	7	98	88	86.	556	15,762
B. 810	Millet, Pearl	3	12	98	82	80.	165	4,677
B. 811	Buckwheat	2	7	99	64	63.	48	1,361
B. 812	Pop Corn, White	1	4	100	100	100	8.5	240
B. 813	Pop Corn, Purple	1	4	100	100	100	8.5	240
B. 814	Bean, Lima (Sieva)	2	15	100	94	94	2.5	71
B. 815	Bean, Henderson's Bush, Lima	2	15	100	100	100	2.5	71
B. 816	Bean, Wonder	5	6	100	80	80	1.5	42
B. 817	Bean, Pole	2	4	100	85	85	4.5	127
B. 818	Pea, Black-eyed	2	6	100	92	92	5.5	156
B. 819	Pea, Lady	1	2	100	100	100	8.5	241
B. 820	Pea, Black	1	16	100	92	92	4.5	127
B. 821	Pea, Whippoorwill	1	4	100	86	86	5.5	156
B. 822	Pea, Cow or Clay	4	6	100	98	98	6.5	184
B. 823	Wheat. White	2	6	100	82	82	22.5	628
B. 824	Wheat, Red	2	6	97	100	97	24	680
B. 825	Corn, Field	2	4	100	100	100	1.5	42
B. 826	Rye	2	4	95	84	80	46	1,304
B. 827	Clover, Red	1	14	90	95	85	704	19,958
B. 828	Timothy Grass	2	7	100	91	91	2,780	78,813
B. 829	Barley	1	4	96	85	82	28	794
B. 830	Oats. Red	1	7	100	95	95	36	1,021
B. 831	Oats. Black	1	7	95	94	89	31	879
B. 832	Oats. White	1	5	100	96	96	39	1,105
B. 833	Grass. Tall Oat	2	14	100	82	82	330	9,355
B. 834	Wheat. White	2	7	100	97	97	30	850
B. 835	Wheat. Red	5	11	100	95	95	29	822
B. 837	Rice	3	14	100	83	83	40	1,134

TABLE XX.—Tests of Old Seeds.

Station Numb'r.	Name.	No. of days before first sprout.	No. of days before last sprout.	Vitality, per cent.
B. 717	Sunflower, Small Russian	0	0	0.
B. 718	Sunflower, Large Russian	4	8	21.
B. 719	Gourd, Southern	10	12	20.
B. 720	Pea, Garden	0	0	0.
B. 721	Pea, Garden	5	5	7.
B. 722	Bean, Large Lima	0	0	0.
B. 723	Bean, Marrowfat	0	0	0.
B. 727	Soufoin	0	0	0.
B. 725	Millet, Golden	5	5	1.
B. 726	Millet, Hungarian	0	0	0.
B. 727	Clover, Mammoth	4.	4.	1.
B. 728	Timothy Grass	0.	0.	0.
B. 729	Randall Grass	5.	7	2.
B. 730	Rye Grass, Italian	5.	5	1.
B. 731	Meadow Foxtail	0	0	0.
B. 732	Johnson Grass	6	6	1.
B. 733	Castor Oil Bean	4	14	5.
B. 734	Oats, Rust Proof	3	17	83.
B. 735	Oats, Black	4	17	71.
B. 736	Buckwheat, Silverhull	0	0.	0.
B. 737	Rice	4	8.	13.
B. 738	Barley	3	8	14.
B. 739	Cotton	0	0	0.
B. 740	Wheat, Flint	0	0	0.
B. 741	Wheat, Fultz	0	0	0.
B. 742	Wheat, Caldwell's Rust Proof	0	0	0.

Discussion of Table XX.—The above samples of seeds were taken from a lot of seeds exhibited by the N. C. Agricultural Department at the State Exposition of 1884, and subsequently at Northern fairs. The seeds were, therefore, six to seven years old. The series is too small to furnish trustworthy data as to the duration of vitality in the species of seeds tested, but the test tends to show that, with the exception of oats, six years is very near the extreme limit. The Station would be glad to receive samples of old seeds of known age for the purpose of enlarging the above series of tests.

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Technical Bulletin No. 2.

THE INJURY OF FOLIAGE BY ARSENITES. A CHEAP ARSENITE. COMBINATION OF ARSENITES WITH FUNGICIDES.

Publications will be sent to any address in North Carolina upon application.

N. C. College of Agriculture and Mechanic Arts,

NORTH CAROLINA

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ON THE CAUSE AND PREVENTION OF THE INJURY TO FOLIAGE BY ARSENITES TOGETHER WITH A NEW AND CHEAP ARSENITE, AND EXPERIMENTS ON COMBINING ARSENITES WITH SOME FUNGICIDES.*

By. B. W. KILGORE, 1st Assistant Chemist.

Early in July, 1890, investigations were commenced with a view of obtaining information as to what insecticides and fungicides may be mixed without impairing the usefulness of either, or endangering the foliage to which they are applied.

It is not the purpose of this article to explain how to apply insecticides and fungicides, nor to tell which particular one should be used to destroy any particular insect or fungus. This is the work of the botanist and entomologist. These investigations were intended to give him material to aid him in his work.

Results, a great many of which are similar to those presented, though not obtained altogether in the same way, were recently published in *Bulletin 10*, of the Iowa Station. I have no desire whatever to question Mr. Gillette's priority in arriving at and announcing his conclusions, but it is a matter of justice to state that *all the conclusions* and nearly all the data here submitted were independently obtained by me before any notice of Mr. Gillette's work reached me.

The three main questions which confronted us in the work were:

1. What is the cause of injury to foliage from arsenites?
2. What will prevent this injury?
3. Will the combination of arsenites with fungicides injure the insecticidal or fungicidal properties of either?

The subject as here treated has to do almost entirely with the first two questions, and work has been devoted to establishing them well.

The investigations were first conducted on a qualitive basis, as that was quicker, and the botanist of the Station desired the results for use in his work. The facts elicited by this preliminary work proved of such interest that a report, in brief the same as here given, was made for present use, and further experiments on a quantitative basis were begun that figures might be presented to bring out more clearly the former results.

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* It is due Mr. Kilgore to say that the experimental work involved in this bulletin was completed in July, 1890, and that the manuscript was prepared exactly in its present shape in September, 1890. For various reasons, it could not be sent to the printer before the present time. In view of similar work being commenced elsewhere at a date later than the above, it is just that Mr. Kilgore should have the credit of the priority for such work as may be considered new.—*The Director.*

357745

I.—CAUSE OF INJURY TO FOLIAGE FROM ARSENITES AND ITS PREVENTION.

It seemed to be the belief of horticulturists and entomologists that the "burning" or "scorching" of foliage when sprayed with arsenites was due to soluble arsenic compounds, though no results had been published to show definitely that such was the case. To test this point, mixtures in the proportion of 1 pound each of White arsenic, London purple and Paris green, separately, in 100 gallons of water, Bordeaux mixture, kerosene emulsion, Eau celeste, and other solutions, were made. After standing twenty-four (24) hours a portion of the the mixture was drawn off and tested qualitively for soluble arsenic compounds, and at the same time another portion was applied to foliage and the effect noted. In no case was injury noticeable where soluble arsenic was absent, but in all cases it was proportional to the amount of soluble arsenic. Seeing in this experiment the insolubility of the arsenites in Bordeaux mixture, and the consequent exemption of foliage from injury, and knowing that London purple was, in the main, an arsenite of calcium, being produced by the decomposition of rosaniline arsenite by calcium hydrate (lime in solution), it was at once plain, from a chemical point of view, that lime would render the soluble portion of the arsenites insoluble in water, and thus render foliage free from injury from them. Various mixtures of an equal weight of pure lime (CaO) and White arsenic, London purple, and Paris green, separately in water, were made to test this point. Some of the mixtures contained as much as four pounds of arsenite in 100 gallons, but in only a few cases was so much as a trace of soluble arsenic found, when tested by sulphuretted hydrogen.

To bring out the above, experiments were conducted and quantitative determinations of soluble arsenic made at the time mixtures were applied to foliage. The results are given in tabulated form in Table I:

TABLE I.—SHOWING THE INJURIOUS EFFECT OF SOLUBLE ARSENIC COMPOUNDS ON FOLIAGE, AND THE POWER OF LIME TO PREVENT SUCH INJURY.

Medium of Solution and Suspension	453 Grams=1 pound to 100 Gallons.	Am't of lime (CaO) in 1 gal. mixture. Grams	Am't of lime (CaO) in 100 gal. mixture. Grams	Time mixture stood. Day	Am't of arsenic trioxide (AS_2O_3) in solution in 1 gal. Grams	Am't of arsenic trioxide (AS_2O_3) in solution in 100 gal. Grams	Injuries to Foliage of Mulberry and Madeira Vines.
Water	White arsenic	------	------	1	.628	62.8	Scorched consid'bly.
		------	------	10	4.098	409.8	All leaves destroyed.
		9.06	906	1	------	------	No injury.*
		9.06	906	10	------	------	No injury.
		4.53	453	1	------	------	No injury.
Water	London purple	------	------	1	.574	57.4	Scorched consid'bly.
		------	------	10	.595	59.5	Scorched consid'bly.
		9.06	906	1	------	------	No injury.
		13.59	1359	1	------	------	No injury.
		4.53	453	1	------	------	No injury.
Water	Paris green	------	------	1	.066	6.6	Slightly scorched.
		------	------	10	.081	8.1	Slightly scorched.
		4.53	453	1	------	------	No injury.
Bordeaux Mixture	Paris green	------	------	1	------	------	No injury.
	London purple	------	------	------	------	------	No injury.

* Burned on making second application. See discussion.

The mixtures all contained 1 pound of the arsenite to 100 gallons. Bordeaux mixture was used as the medium of suspension in the last two experiments. Extensives applications of mixtures to foliage could not be made, as Madeira vines and mulberry leaves were the only suitable plants convenient to the laboratory. The effect in these two cases, however, is so strongly marked as to leave little doubt of what the effect on other foliage will be. In every case where there was soluble arsenic there was also "burning" of foliage, and this in all cases was in direct proportion to the amount of soluble arsenic. Where there was no arsenic in solution, there was no burning of leaves, except in the one case noted* in Table I, where white arsenic and lime had been standing only twenty-four hours. The application in this case was made in the same way as all the others—by sprinkling the liquid on the leaves. At the end of one week no injury was perceptible, when another application was made. In a few days the leaves were rather badly spotted with "burnt" places. I consider this due to the fact that all the white arsenic at the time of the first application, had not gone into solution to be precipitated by the lime, and hence dried upon the leaves as white arsenic and was dissolved by the second application and then burned the leaves. It would be safer, where white arsenic is used, to get it all into solution and allow it to be changed by lime into the insoluble arsenite of lime, thus removing danger of injury from a second application, from dew, or light rain. Here is an arsenite very much the same as London purple, that can be used with as great freedom as the latter, even after lime has been added to render it harmless to foliage. More of this later.

Again, it will be seen from Table I that lime, in all cases where it was added to the mixtures at the time they were made, changed immediately all soluble arsenic compounds into insoluble ones as fast as they came into solution. The Bordeaux mixture contained sufficient lime, and it was not necessary to add more.

TABLE II.—SHOWING AMOUNT OF SOLUBLE ARSENIC COMPOUNDS EXPRESSED AS ARSENIC TRIOXIDE (As_2O_3) ARSENICAL MIXTURE AT DIFFERENT TIMES.

MIXTURE.	1 Hr. Am't As_2O_3 in		3 Hrs. Am't As_2O_3 in		5 Hrs. Am't As_2O_3 in		7 Hrs. Am't As_2O_3 in		24 Hrs. Amt As_2O_3 in		10 Days. A'mt As_2O_3 in	
	1 gal.	100 gals.	1 gal.	100 gals.	1 gal.	100 gals.	1 gal.	100 gals.	1 gal.	100 gals.	1 gal.	100 gals.
	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms	Grms
*1 lb. white arsenic in 100 gals. water	.053	5.3	.223	22.3	.276	27.6	.333	33.3	.628	62.8	4.098	409.8
1 lb white arsenic and 2 lbs. lime in 100 gals. water	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. white arsenic and 1 lb. lime in 100 gals water	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. London purple in 100 gals. water	.517	51.7	.520	52.0	.522	52.2	.530	53.0	.574	57.4	.595	59.5
1 lb. London purple and 2 lbs. lime in 100 gals. water	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. London purple and 3½ lbs. lime in 100 gals. water	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. Paris green in 100 gals. water	.057	5.7	.060	6.0	.061	6.1	.058	5.80	.066	6.6	.081	8.1
1 lb. Paris green and 1 lb. lime in 100 gals. water	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. Paris green in 100 gals. Bordeaux mixture	0	0	0	0	0	0	0	0	0	0	0	0
1 lb. London purple in 100 gals. Bordeaux mixture	0	0	0	0	0	0	0	0	0	0	0	0

*1 pound equals 453½ grams.

Table II shows the amount of soluble arsenic compounds, expressed as grams of arsenic trioxide (As_2O_3) in 1 gallon and in 100 gallons, in arsenical mixtures at different times after mixing when lime was not added; and in like manner shows the absence of such compounds when lime was present. White arsenic, it will be seen, dissolves very slowly, requiring more than ten days for complete solution, even in such a large volume of water, and at summer temperature. While the soluble portion of London purple goes into solution practically at once, and the same is approximately true of Paris green.

London purple is, in the main, a mixture of arsenite of lime and arsenite of rosaniline. The latter is very soluble in water, to which it gives the red color so characteristic of London purple mixtures. It is from this rosaniline arsenite that the soluble arsenic is derived, and to which the "burning" of the foliage is, no doubt, due. The ready solubility of this compound also makes clear the reason that the injury to foliage from London purple mixtures is as great when freshly mixed as after having stood for days. The beneficial effect of lime in the London purple mixture is due to its decomposing action upon the rosaniline arsenite by which insoluble arsenite of lime is formed. This change takes place in a short time, as will be seen from the loss of color of the mixture. Double and triple weights of lime to London purple were experimented with, thinking it might require these amounts to effect the decomposition, but an equal weight was found to be ample.

The beneficial effect of lime in Paris green and White arsenic mixtures is also due to the formation of the insoluble arsenite of lime. Equal weight of lime to Paris green and White arsenic each was found sufficient in all cases, and no more than this, even of the commercial article, need be added to Paris green. But to be on the safe side, I think it best to add 2 pounds commercial lime (CaO) to 1 pound white arsenic. One pound white arsenic (As_2O_3) requires approximately 0.85 pounds of lime (CaO) to satisfy the reaction in the production of the insoluble arsenite, but slight excess of lime does not seem to do any harm—certainly far less than an excess of arsenic.

II.—A Cheap Arsenite.

A very cheap insecticide, having the same insecticidal properties as London purple, can be easily made by boiling together for one-half hour in 2 to 5 gallons of water—

1 Pound Commercial White Arsenic,
2 " " Lime,

and dilute to required volume, say 100 gallons. The White arsenic can be obtained in quantities of 10 pounds for 8 to 12 cents per pound. Cost of lime will add very little to this. It is desirable that the lime should be present in the boiling solution of White arsenic since it renders the latter insoluble as fast as it goes into solution, thus reducing the volume of water and shortening the time for obtaining the arsenite. When the White arsenite is dissolved alone, a larger volume of water and more time are required. When lime is added the precipitation goes on slowly, requiring more than twenty-four hours to reach completion.

III.—Combining Arsenites With Fungicides.

Copper sulphate (blue stone), iron sulphate (copperas), and iron chloride are generally used as fungicidal washes. To test the solubility of arsenites in solutions of these, mixtures were made, as indicated in Table III, and the soluble arsenic determined after 3 and 20 hours. The mixtures were applied to foliage at the end of 20 hours. This was done by dipping small twigs of mulberry, maple, ivy, snow berry, spirea, fig, chrysanthemum, canna (leaf), and some others into the mixtures and allowing them to stand with their petioles in water for one week, when the effect was noted. The experiment, though rather crude and limited, points in its effect to the same conclusion drawn from Table I: That soluble arsenic burns the foliage, and that the burning is in direct proportion to the amount of soluble arsenic. This table also shows the greater solubility of the arsenites in these solutions than in pure water, especially after they have stood for a time; and indicates that, when used together at all, the sooner the application is made after mixing, the better.

Table III.—SHOWING AMOUNT OF SOLUBLE ARSENIC IN ARSENICAL MIXTURES, HAVING IN SOLUTION *COPPERAS*, *COPPER-SULPHATE*, AND *IRON CHLORIDE*, TOGETHER WITH THE EFFECT ON FOLIAGE.

MIXTURE.	3 Hours. Am't As_2O_3 in		20 Hours. Am't As_2O_3 in		EFFECT ON FOLIAGE.
	1 gal.	100 gals.	1 gal.	100 gals.	
1 lb. white arsenic and 1 lb. copperas in 100 gal. water	.352	35.2	.997	99.7	Scorched consid'bly.
1 lb. Paris green and 1 lb. copperas in 100 gals. water	.174	17.4	.482	48.2	Scorched, but not so much as above by one-half.
1 lb. Paris green and 4 lbs. copper sulphate in 100 gals. water	.051	5.1	.109	10.9	Scarcely any injury.
1 lb. Paris green and 4 lbs. iron chloride in 100 gals. water	.550	55.0	.976	97.6	Scorched consid'bly.
1 lb London purple and 4 lbs. iron chloride in 100 gals. water	.746	74.6	.894	89.4	Slightly less than above.
1 lb. white arsenic and 4 lbs. chloride iron in 100 gals. water	.518	51.8	1.475	147.5	Worst result in whole lot; burned rather badly.

Arsenites in Bordeaux Mixture.

Tables I and II show the absence of soluble arsenic where Paris green and London purple are mixed with standard Bordeaux Mixture, and the same would be true of White arsenic. Practical tests of the effect upon foliage of combinations of Paris green and London purple, each with Bordeaux Mixture, were made. These combinations contained one pound of Paris green and one pound of London purple separately in 150 gallons of Bordeaux Mixture and applied to fig, grape, mulberry, blackberry, peach, pear, and apple leaves. Each mixture was tested for soluble arsenic, but none was found in any case. Nor did the slightest injury result to any of the leaves from these combinations. Some experiments were also made with combinations containing 1 pound of the arsenites to 100 gallons of Bordeaux Mixture with the same results as the above. Both theory and practice show these combinations to be perfectly harmless to foliage, and that they may be used with freedom.

ARSENITES IN EAU CELESTE, AND EAU CELESTE MODIFIED WITH SODA.

Mixtures of Paris green and London purple, 1 pound each to 100 gallons Eau Celeste and Eau Celeste modified with soda were made, and after standing 24 hours were applied to foliage and tested qualitatively for soluble arsenic. The foliage was almost completely destroyed and the quantity of soluble arsenic extremely high. Ammonia and sodium carbonate are greedy solvents of arsenites; hence, arsenites should not be mixed in these solutions as now made.

ARSENITES IN KEROSENE EMULSION.

Paris green and London purple do not mix well with kerosene emulsion. The particles stick together and become lumpy; besides, the emulsion is slightly decomposed by London purple, and the soaps used in making the emulsion are always alkaline and render the arsenites more soluble than in water.

IV.—CONCLUSIONS.

1. When soluble arsenic compounds were absent there was no injury to foliage.
2. When soluble arsenic compounds were present the foliage was always "scorched."
3. That the injury was in all cases in direct proportion to the amount of soluble arsenic compounds present.
4. Consequently it is soluble arsenic compounds that "burns" and "scorches" foliage when sprayed with arsenites.
5. That lime prevents this injury by changing soluble arsenic compounds to the insoluble arsenite of lime.
6. That London purple and Paris green mixtures with lime may be applied to foliage with as great safety after one hour as ten days after mixing.
7. Because all arsenites in London purple and Paris green capable of solubility are changed by lime almost immediately into insoluable arsenite of lime.
8. That the longer white arsenic mixture with lime has stood before applying to foliage, the better.
9. For the complete change to insoluble arsenite requires several days.
10. That the above change can be greatly shortened by treating the white arsenic and lime together for a short time with boiling water.
11. That when white arsenic is dissolved alone, and lime added afterwards, 6 to 24 hours are required for all soluble arsenic to be precipitated.

12. But when mixed together the insoluble arsenic is formed as fast as soluble arsenic goes into solution.

13. That after white arsenic has stood for a time in water, the mixture should not be applied to foliage without first adding lime.

14. That Bordeaux mixture prevents the solubility of the arsenites and their injury to foliage by virtue of its lime.

15. That the arsenites are more soluble in simple solutions of sulphate of copper, sulphate of iron, and chloride of iron than in water, and injure foliage more than when applied in water.

16. That the arsenites are very soluble in Eau Celeste and Eau Celeste modified with soda mixtures, and do very great damage to foliage when applied in them.

17. That the kerosene emulsion is not a favorable medium for applying the arsenites.

NOTE.—To prevent lime from becoming lumpy when added to mixtures, it should be slaked in a small volume of water and all the lumps well broken.

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North Carolina

Agricultural Experiment Station.

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Technical Bulletin No. 3.

I. THE DIGESTIBILITY OF COTTON SEED HULLS.

II. THE DIGESTIBILITY OF A RATION OF COTTON SEED HULLS AND COTTON SEED MEAL.

III. COMPARISON OF COMPOSITION AND DIGESTIBILITY OF WHEAT STRAW AND COTTON SEED HULLS.

IV. THE FERTILIZING CONSTITUENTS RECOVERED IN MANURE IN THESE EXPERIMENTS.

Publications will be sent to any address in North Carolina upon application.

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NORTH CAROLINA

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DIGESTION EXPERIMENTS.

By F. E. EMERY, Agriculturist, and B. W. KILGORE, First Ass't Chemist.

I. DIGESTIBILITY OF COTTON SEED HULLS.

In feeding experiments heretofore conducted at this Station and elsewhere with cotton seed hulls, the digestibility has been assumed to be equal to that of wheat straw in the several nutritive constituents which make a fodder valuable. Where this by-product is produced in large quantities it becomes of importance to cotton farmers and stock feeders to know something more definite in regard to its value for cattle food. There have already been feeding experiments enough made with cotton seed hulls at Southern Experiment Stations, and on a commercial scale by gentlemen who are interested in disposing of this by-product, to show that it can be used profitably with cotton seed meal or other grain in the production of fat cattle.

It yet remained to determine the digestibility of the hulls as fed separately for maintenance, and in a ration with meal as used for fattening in order to give us some other than empirical means for compounding rations, and to put the feeding of cotton seed hulls on the same rational basis as has been established for so many other cattle foods.

It was expected that a first digestion on some other food would have to be made and the hulls added to it, but a Jersey cow with a good appetite, one that kept habitually in good order on a rather poor diet, gave the means of making a direct determination. After the digestibility of the cotton seed hulls alone had been determined, cotton seed meal was added and a determination made of the digestibility of the ration thus made.

Since no digestion work has been done before at this Station it may be well to enter somewhat into the details and show, for those readers who are not familiar with the work, *how a digestion experiment is made.*

The animal selected for the experiment is fed a known uniform amount of the food, the digestibility of which is to be determined for at least six days before the real work begins. The food actually eaten is found by weighing that fed, weighing and drying waste, and subtracting dry matter of waste from dry matter of food fed. The solid excrement is collected and analyzed, and the constituents subtracted from the corresponding ones in the food eaten ; the difference is the amount digested less a small amount which comes from bile compounds and wear and tear of the digestive track. This error can be nearly corrected by dissolving out the bile products with alcohol and ether. Then by dividing the amounts of each food compound digested by the amount of the same compound in the food eaten the per cent. digested is obtained. These last are called the *co-efficients of digestibility*.

Another question connected with the digestion may be considered for which the nitrogen consumption and excretion are the factors, to determine whether the animal is gaining or losing flesh, or just being supported by the ration. In the work under discussion both milk and urine were examined chemically for this purpose.

DATA COLLECTED AT THE STABLE.

The Jersey cow, Belle of Brookside, was kept on a diet of cotton seed hulls and waste from other cows for some time before this digestion work was begun. After November 30th, 1890, this cow was bedded with sawdust and fed only cotton seed hulls until the conclusion of the digestion period with hulls alone.

Due preparation was made and collection of both solid and liquid excrements were begun at noon of December 8th. These were carefully sampled each day at noon. The samples were weighed and taken at once to the laboratory. The cow was nearly dry at the time this experiment began and was milked but once daily. At every feeding two ounces more than was required was weighed and the two ounces removed from different parts of the hulls were placed in a tight jar and kept for analysis until the end of the experiment. The whole of the waste from each feed was weighed, thoroughly mixed on a clean floor, and a sample of about 8 ounces was taken from which a water determination was to be made. Water was offered twice daily at regular times, and the amount drank is recorded in the table for stable record, where will be found the record of live weight every morning before feeding or watering.

The weather during this period, December 1st to 12th, 1890, was mild, but two days were raw and cold. The cold was not, however, intense enough to cause much, if any, discomfort in the stable. The rainfall was 1.49 inches, all occurring on the 7th and 8th. Cloudiness, 0.5, on scale of 0 to 10; cloudless days, 1st, 2d, 9th and 10th; fair days, 4th, 5th, 11th and 12th; highest temperature, 67° F. on 11th; lowest temperature 28° F. on 7th and 8th; mean temperature, 1st–12th, 43.6° F.; mean relative humidity, 1st–12th, 74.8 per cent.; mean height of barometer, 30.037 inches; highest barometer, 30.287 inches on the 5th; lowest barometer, 29.773 inches on the 11th.

The environment of an animal has so much to do with their well-being, and may effect them in so many ways, especially if such is the canse of bodily discomfort, or mental excitement, that this summary is regarded as an essential part of the record, as well as the fact that this cow was of a particularly mild disposition and never for the whole time seemed to be in the least annoyed by the presence of the attendants.

TABLE I.

STABLE RECORD OF DIGESTION EXPERIMENT No. 1.

December, 1890.	Cotton Seed Hulls.						Water Drank.		Fasted	Excrements.		Milk in Ozs.
	A. M.		M.		P. M.		A. M.	P. M.	Live Wght. Lbs.	Solid.	Liquid.	
	Fed. Lbs.	Waste. Ozs.	Fed. Lbs.	Waste. Ozs.	Fed. Lbs.	Waste Ozs.	℔s. Ozs.	℔s. Ozs.		℔s. Ozs	℔s. Ozs.	
1	8	46	8	40	8	18	00–00	19–6	926	....	....	20
2	8	41	8	38	7	8	4–00	26–6	923	....	....	17
3	7	40	7	64	7	78	20–00	9–6	926	....	....	16
4	7	32	7	48	7	27	00–7	26–2	926	....	....	22
5	7	20	7	76	7	24	4–2	27–6	926	....	....	14
6	7	17	7	68	7	10	8–12	20–00	932	....	....	18
7	7	36	7	48	7	10	6–00	30–00	936	....	....	10
8	7	2	7	64	7	78	19–3	00–00	912	....	....	24*
9	7	29	7	48	7	39	24–6	00–00	912	23–3	6–12	12
10	7	20	7	50	7	28	11–3	30–7	908	21–14	00–00	12
11	7	58	7	71.5	7	37	00–00	24–4	922	28–00	5–00	12
12	7	6	......	....	......	....	00–00	....	924	20–6½	2–11½	14

*Milked as usual in the morning and again at midday to conform to the time of taking other samples. Milking at noon on all days for which samples were analyzed.

Cotton Seed Hulls.—Hulls from different and even from the same mill vary widely in composition owing to the adherence of larger or smaller quantities of the finely broken kernels. Such variation may occur in the analysis of the same lot from imperfect sampling, or in the same sample from imperfect mixing of the different parts of the ground hulls. The former source of error was avoided by drawing two ounces of hulls from each weighed feed, preserving in air-tight jars till end of experiment, then mixing and sampling for analysis. The waste hulls were treated in a similar way. All precautions were used by the analyst to secure a uniform mixture of ground samples for analysis.

Solid Excrement.—The total solid excrement was thoroughly mixed at the end of each day, sampled, and the sample dried, first in water bath and then in hydrogen bath to constant weight, as were the waste hulls also. The solid excrement for each day was analyzed separately and the percentage composition is shown in Table III, along with that of the hulls and meal fed and waste hulls.

The chemical methods followed were those of the Association of Official Agricultural Chemists.

In Table II we have total weight of waste hulls for each feed, and total solid excrement for each day, with the per cent. of water and dry matter they contain. These determinations were made in the case of the hulls after each feed, and at the end of each day in the case of solid excrement. It was only by this means that the correct amount of dry matter could be obtained, since the quantity of hulls and excrement together with the per cent. of water each contained, varied considerably with each feed and day.

TABLE II.

SHOWING WASTE HULLS AND SOLID EXCREMENT, WITH PER CENTAGES OF WATER AND DRY MATTER.

1890.		Total Ounces.	Water. Per Cent.	Dry Matter. Per Cent.
Dec. 8	Waste hulls, noon feed	64	15.62	84.38
8	Waste hulls, p. m. feed	78	15.34	84.66
9	Waste hulls, a. m. feed	29	15.05	84.95
9	Waste hulls, noon feed	48	14.68	85.32
9	Waste hulls, p. m. feed	39	14.39	85.61
10	Waste hulls, a. m. feed	20	14.22	85.78
10	Waste hulls, noon feed	50	13.70	86.30
10	Waste hulls, p. m. feed	28	14.13	85.87
11	Waste hulls, a. m. feed	58	15.55	84.45
11	Waste hulls, noon feed	71.5	13.33	86.67
11	Waste hulls, p. m. feed	37	13.38	86.42
12	Waste hulls, a. m. feed	6	13.80	86.20
9	Solid excrement	371	66.97	33.03
10	Solid excrement	350	67.99	32.01
11	Solid excrement	448	69.59	30.41
12	Solid excrement	326.5	68.57	31.43
1891.				
Jan. 6	Solid excrement	594.5	70 13	29.87
7	Solid excrement	680.5	69.99	30.01
8	Solid excrement	592	71.21	28.79
9	Solid excrement	631	67.93	32.07

In Table IV is given the amount of solid excrement for each day and for the whole period, with the amounts in ounces of its constituent nutrients. This table also shows the total amount of hulls consumed and digested, with the digestibility of the hulls as a whole and of the constituents.

TABLE III.

SHOWING PER CENTAGE COMPOSITION.

1890.		Water. Per Cent.	Dry Matter. Per Cent.	DRY MATTER CONTAINS				
				Ash. Per Cent.	Albuminoids (N x 6.25). Per Cent.	Fat (Ether Extract). Per Cent.	N. Free Extract. Per Cent.	Crude Fiber. Per Cent.
	Cotton seed meal used	6.93	93.07	7.36	43.04	10.94	30.14	8.52
	Cotton seed hulls used	11.44	88.56	3.31	4.94	6.11	40.11	45.53
	Waste cotton seed hulls.	10.11	89.89	3.34	4.59	6.00	37.55	48.52
Dec. 8—9	Solid excrement	2.88	97.12	3.92	6.11	2.03	39.67	48.27
9—10	" "	3.07	96.93	3.64	6.06	1.58	39.64	49.08
10—11	" "	3.84	96.16	3.90	6.17	1.71	37.28	50.94
11—12	" "	6.34	93.66	3.44	5.87	2.20	38.98	49.51
Jan. 5—6	" "	8.40	91.60	4.45	9.14	2.13	34.35	49.93
6—7	" "	1.72	98.28	4.68	10.30	2.31	33.73	48.98
7—8	" "	00.00	100.00	4.58	10.25	2.51	35 06	47.60
8—9	" "	00.00	100.00	4 60	10.31	2.44	33.92	48.73

TABLE IV.

SHOWING NUTRIENTS CONSUMED AND EXCRETED, WITH PER CENTAGES DIGESTED.

1890.		Total Amount. Ozs.	Dry Matter. Ozs.	DRY MATTER CONTAINS				
				Ash. Ozs.	Albuminoids (N x 6.25). Ozs.	Fat (Ether Extract). Ozs.	N. Free Extract. Ozs.	Crude Fiber. Ozs.
Dec. 8—9	Solid excrement	371	122.54	4.80	7.49	2.49	48 61	59.15
9—10	" "	350	112.04	4.08	6.79	1.77	44.41	54.99
10—11	" "	448	136.24	5.31	8 41	2.33	50.79	69.40
11—12	" "	326.5	102.62	3.53	6.02	2.26	40.00	50.81
	Total solid excrement	1495.5	473.44	17.72	28.71	8 85	183.81	234.35
	Total consumed		738.80	24 32	38.08	45.64	307.89	322.90
	Total solid excrement		473.44	17.72	28.71	8.85	183.81	234.35
	Total digested		265.36	6.60	9.37	36.79	124.08	87.55
	Per cent. digested		**35.92**	**27.14**	**24.61**	**80.61**	**40.30**	**27.11**

Nutritive ratio of cotton seed hulls 1 : 29.6.

II. DIGESTIBILITY OF A RATION OF COTTON SEED HULLS AND COTTON SEED MEAL.

After the digestion with cotton seed hulls alone, the same cow was fed about as many pounds of cotton seed hulls as were consumed on hulls alone, and three pounds of cotton seed meal per day were added for a ration, one pound being fed on the hulls at each feed. This addition of meal brought an increase in the consumption of hulls and they were gradually increased to 21 pounds per day, which did not then reach the maximnm of the cow's appetite, since this was all eaten for a considerable period.

During the first part of this period on cotton seed meal during the increase of hulls the body weight fell off rapidly, but the loss was quickly regained and continued very regular to the end of the digestion work. These weights averaged as follows:

November	30 to	December	12,	13 days,	average	weight	921	pounds.
"	30 "	"	8,	9 "	"	"	923	"
December	9 "	"	12,	4 "	"	"	916.5	"
"	13 "	"	27,	15 "	"	"	901.7	"
"	13 "	"	23,	11 "	"	"	894	"
"	24 "	"	27,	4 "	"	"	923	"
"	28 "	January	9,	13 "	"	"	938.4	"
"	28 "	"	5,	9 "	"	"	938.5	"
January	6 "	"	9,	4 "	"	"	938.3	"

The food was continued as above (21 pounds cotton seed hulls and 3 pounds cotton seed meal) until January 5th, when collections were again begun and continued four days, and the results recorded below were obtained.

During the period covered by Table V the food offered was 7 pounds cotton seed hulls and 1 pound cotton seed meal at each of three feeds daily. There was no waste for the whole period, except on December 29th and 30th 43 ounces and 11 ounces respectively of cotton seed hulls.

TABLE V.

STABLE RECORD DIGESTION EXPERIMENT WITH COTTON SEED HULLS AND MEAL.

1890—'91.	Water Drank.		Fasted Live Weight.	Milk Yielded.	Solid Excrement.	Urine.
	A. M.	P. M.				
	Lbs. Ozs.	Lbs. Ozs.	Lbs.	Ozs.	Lbs. Ozs.	Lbs. Ozs.
Dec. 28	18–4	20–13	936	16	....	....
29	00–00	40–5	939	19	....	....
30	00–00	11–15	942	18	....	....
31	28–4	24–5	933½	18	....	....
Jan. 1	8–2	32–2	941½	20	....	....
2	19–00	32–0	937	19	....	....
3	00–00	35–2	945	18	....	....
4	10–1	32–1	933	20	....	....
5	00–00	37–11	937½	18	....	....
6	8–12	22–13	935	18	37–2½	9–15
7	39–14	00–00	929	21	42–8½	11–1½
8	21–00	38–9	934	18½	37–00	7–10
9	00–00	28–1	955	18½	39–7	7–10½

During this later period, December 29th, January 9th, there was a fall of .80 inch of rain, which occurred December 31 and January 1 and 2. There were 6 clear days, viz.: December 29, 30, and January 5, 6, 7 and 8. January 3d was fair. The highest temperature was 62° F. on January 2d, and the lowest, 22° F., occurred on the 6th. Mean temperature, 39 F. Mean relative humidity, 60.5 per cent. This low per centage of relative humidity indicates that at the temperatures given the usual chill of the air was much reduced by the lack of moisture and animals were therefore much more comfortable at the same temperature than with an ordinary amount of moisture in the air.

	Total Dry Matter. Ozs.	DRY MATTER CONTAINS IN OUNCES				
		Ash.	Albuminoids. (Nx6.25)	Fat (Ether Extract).	N. Free Extract.	Crude Fiber.
Fed in cotton seed hulls......	1190.24	39.40	58.80	72.72	477.40	541.92
Fed in cotton seed meal......	178.69	13.15	76.91	19.55	53.86	15.22
Total consumed..........	1368.93	52.55	135.71	92.27	531.26	557.14
Solid excrement...............	754.60	34.58	75.59	17.72	258.28	368.44
Total digested.	614.33	17.97	60.12	74.55	272.98	188.70
Per cent. digested..............	**44.9**	**34.2**	**44.3**	**81.**	**51.4**	**33.9**

Nutritive ratio of ration 1 pound cotton seed meal to 7 pounds cotton seed hulls, 1:10.8.

Cotton hulls from the same lot used, for the digestion of hulls alone, were used in this experiment. It was therefore deemed unnecessary to collect another sample and make another analysis. The composition of the hulls and meal fed together with that of the solid excrement for each day for this digestion will be found in Table III. The amount of solid excrement for each day, with its per centage of water and dry matter, is given in Table II.

It has been shown* that where a coarse fodder, rich in carbohydrates and comparatively poor in protein—one in which the "ratio" is wide, is fed alone, the digestibility of both carbohydrates and protein are decreased. Hence, while an animal may be supported for a considerable time on such fodder, there is a loss of a part of the digestible protein of both in addition to the loss of "condition" of the animal. Therefore, in all cases where such a fodder is to be consumed it is on the side of economy and in the interest of the feeder to add some by-product, as cotton seed meal, which is one of the very best to use in order to get the most out of the coarse food and feed the animal to the best advantage. Just how much meal should be fed with a coarse fodder varies very widely.

1st. According to the ratios existing between the protein and carbohydrates of both coarse food and meal.

2d. The kind and age of animal which is to consume the food.

3d. The object of feeding, whether for maintenance, beef, milk or work.

III. COMPARISON OF COMPOSITION AND DIGESTIBILITY OF WHEAT STRAW AND COTTON SEED HULLS.

Since it has been assumed in previously conducted experiments that the digestibility of cotton seed hulls is parallel to that of wheat straw this comparison has been deemed of sufficient interest to find a place here. The data in regard to the hulls being that obtained in the foregoing experiment.

TABLE VI.

COMPARISON BETWEEN COTTON SEED HULLS AND WHEAT STRAW.

	COTTON SEED HULLS.			WHEAT STRAW.		
	Per centage composition. 10 analyses. Comp. by F. E. E.	Per cent. of constituents digestible. Above determined.	Pounds digestible in 100 of Hulls.	Per centage composition. Ct. E. S., '87. 6 analyses.	Per cent. of constituents digestible. (Wolf's Tables.)	Pounds digestible in 100 of Straw.
Dry matter...........	90.08	35.9	....	91.22		....
Ash	2.87	27.1	....	....		....
Protein (N x 6.25)...	4.23	24.6	1.04	3.45	26	0.897
Fat (Ether Extract)..	2.24	80.6	1.81	1.29	27	0.348
Nitrogen-Free Ex'ct	33.20	40.3	13.38	37.33	40	14.93
Crude Fiber........ .	47.44	27.1	12.86	44.99	52	23.39
Nutritive Ratio.......	....	....	29.6	....	....	43.7

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*Armsby's Manual of Cattle Feeding, Part II, Chap. I.

IV. FERTILIZING CONSTITUENTS RECOVERED IN MANURE IN THESE EXPERIMENTS.

This experiment to determine the digestibility of cotton seed hulls also furnishes data to show what proportion of the fertilizing constituents fed are returned in the excrement (dung, urine and milk). The following table contains the percentages and amounts of the different fertilizing elements in the hulls fed, and in the dung, urine, and milk excreted:

TABLE VII.

FERTILIZING CONSTITUENTS IN COTTON SEED HULLS FED AND EXCRETED DURING DIGESTION EXPERIMENT.

	Total Amount. Oz.	Dry Matter. Oz.	CONTAINING					
			Nitrogen in		Phos. Acid. (P_2O_5) in		Potash (K_2O) in	
			Pr. Ct.	Oz.	Pr. Ct.	Oz.	Pr. Ct.	Oz.
Fed in cotton seed hulls—4 days........	834.33	738.80	.790	5.837	.199	1.470	1.806	13.343
Excreted in dung—4 days....................	1495.5	473.44	.968	4.583	.371	1.756	1.180	5.587
Excreted in urine—4 days....................	231.5	....	.814	1.884	.051	.118	1.638	3.792
Excreted in milk—4 days....................	50.	....	.579	.289	......	....	....	....
Total excreted..	1777.0	....	......	6.756	.....	1.874	....	9.379
Fed and not excreted..	....	....	......	....	......	....	....	3.964
Excreted and not fed..	....	....	......	.919	......	.404	....	....
Per cent. excreted......	....	....	......	**115.74**	......	**127.48**	....	**70.29**

The milk and urine were analyzed each day to prevent loss from decomposition. From this table it will be seen that more nitrogen and phosphoric acid were excreted than fed. This increase of nitrogen excreted over that fed is no doubt due to loss of flesh during the experiment and indicates that cotton seed hulls did not constitute a *maintenance ration* for the animal. To ascertain if cotton seed hulls alone would keep an animal without loss of flesh was another object of the experiment, and the above table contains figures of interest, pointing to a negative answer.

The following table contains like results to the foregoing for a ration of cotton seed hulls and meal, in which three pounds of cotton seed meal were fed each day or 12 pounds during the four days:

TABLE VIII.

FERTILIZING CONSTITUENTS IN COTTON SEED HULLS AND MEAL FED AND EXCRETED DURING DIGESTION EXPERIMENT.

	Total Amount. Oz.	Dry Matter. Oz.	CONTAINING					
			Nitrogen in		Phos. Acid ($P_2 O_5$) in		Potash ($K_2 O$) in	
			Pr. Ct.	Oz.	Pr. Ct.	Oz.	Pr. Ct.	Oz.
Fed in cotton seed hulls—4 days......	1344	1190.24	.790	9.403	.199	2.369	1.806	21.496
Fed in cotton seed meal—4 days	192	178.69	6.886	12.304	2.89	5.164	2.138	3.820
Total in food............	1536	1368.93	....	21.707	....	7.533	....	25.316
Excreted in dung—4 days	2498	754.60	1.600	12.074	.837	6.316	1.207	9.108
Excreted in urine:								
1st day................	159	....	1.22	1.940	.084	.134	1.202	1.911
2d day.................	187	....	1.10	2.057	.089	.166	1.374	2.570
3d day.................	122	....	1.26	1.537	.087	.106	1.273	1.553
4th day	122.5	....	1.36	1.666	.090	.110	1.243	1.523
Total excreted in urine..................	590.5	....	....	7.200	....	.516	....	7.557
Excreted in milk—4 days..................	76 0	....	.565	.429	....	....	....	....
Total excreted..........	3164.5	....	....	19.703	....	6.832	....	16.665
Fed and not excreted.	....	....	....	2 004	....	.701	....	8.651
Per cent. excreted.....	....	....	....	**90.76**	....	**90.69**	....	**65.82**

The fertilizing elements excreted in this case were all below the quantities fed. This excess of nitrogen fed over that excreted indicates that the animal was gaining flesh on this ration, instead of losing, as she was when eating hulls alone.

This table shows that over 90 per cent. of the nitrogen and phosphoric acid and nearly 66 per cent. of the potash fed were excreted and recovered in the manure. It is usually estimated that 80 per cent. of the fertilizing constituents fed in a food-stuff are excreted in the manure. The experiment at hand gives 82.42 per cent., while the first on an insufficient diet (cotton seed hulls alone) gave 104.62 per cent., or more than the quantities fed.

An inspection of Table IX and the two preceding tables will show that the value of farm-yard manure depends upon what is fed. Cotton seed hulls, being poor in fertilizing elements, furnish a manure correspondingly low in value. The meal, on the other hand, is very rich in fertilizing constituents and enhances the value of the manure in proportion to the amount of it fed with hulls or other coarse fodders.

TABLE IX.

THE AMOUNT IN OUNCES OF FERTILIZING CONSTITUENTS AND VALUE EXCRETED IN DUNG AND URINE DURING THE FOUR DAYS.

	Feed 834.33 ounces of Cotton Seed Hulls.						Feed { 1344 ozs. Cotton Seed Hulls. 192 ozs. Cotton Seed Meal.					
	Feed.		Dung.		Urine.		Feed.		Dung.		Urine.	
	Ozs.	Value. Cents.	Ozs.	Value. Cents.	Ozs.	Value. Cents.	Ozs.	Value. Cents.	Ozs.	Value. Cents.	Ozs.	Value. Cents.
Nitrogen.....	5.83	5.7	4.58	4.5	1.88	1.8	21.70	21.3	12.07	11.8	7.20	7.1
Phos. Acid..	1.47	0.5	1.75	0.5	.12	.04	7.53	2.3	6.31	2.0	.51	0.2
Potash........	13.34	4.2	5.58	1.8	3.79	1.2	25.31	7.8	9.10	2.8	7.55	2.4
Total value..	....	10.4	....	6.8	....	3.04	....	31.4	....	16.6	....	9.7

The above figures make apparent the value of urine as a fertilizer. Its richness depends upon that of the food. In both of the above experiments about one-third of the nitrogen and nearly one-half of the potash excreted were in the urine while most of the phosphoric acid was in the solid excrement.

In determining the digestibility of a food by direct experiment with animals, two factors enter to make the co-efficient for albuminoids apparent rather than real. When the albuminoids are reckoned, as they often are, from the total nitrogen content of the food the amides, if present, tend to make the co-efficient too large. While the bile acids and coloring matters, mucus and other intestinal products containing nitrogen and not belonging to the the undigested food residue proper tend to depress it. The intestinal products may cause an error of several per cent. in the albuminoid co-efficient of coarse fodders of low nitrogen content.

In the table that follows is contained data on the above two points for the two digestions given in this Bulletin.

TABLE X.

PERCENTAGE OF NITROGEN IN THE DIGESTION EXPERIMENTS.

	NITROGEN IN 100 PARTS, AIR-DRY SUBSTANCE.				
	Total.	Albuminoid.	Non-albuminoid.	Total after extraction with ether, alcohol, hot water and cold lime water.	Difference from total nitrogen.
		Per Cent.	Per Cent.	Per Cent.	Per Cent.
Cotton seed hulls........................	.7	.70	.0	.66	.04
Cotton seed meal........................	6.41	6.36	.05	....	....
Fæces from cotton seed hulls.........	.94	....	....	.91	.03
Feces' from cotton seed hulls and meal.........	1.53	....	....	1.42	.11

The albuminoid nitrogen was determined by Stutzer's method, and the bile and intestinal products, as indicated in table, by extraction with ether, alcohol, hot water and cold lime water, a method used by the Maine State Experiment Station (see Report for 1888, pp. 198—203), and is claimed to give very satisfactory results. The difference between total nitrogen before and after extraction is given as fecal nitrogen not belonging to the undigested food residue. These differences are so small in our work within the error of analysis, especially when so much manipulation is involved, that no account was taken of them in making up the co-efficients.

Notice was taken of the solid excrement for "jelly-like" substance, but it was observed to be remarkably free from them, which fact likely explains the close agreement of total nitrogen before and after extraction.

No account was taken of the non-albuminoid nitrogen, as the amount was very small and the quantity of meal fed was also small.

November 26, 1892.

North Carolina

Agricultural Experiment Station,

Bulletin No. 87d

Technical Bulletin No. 4.

DIGESTION EXPERIMENTS
WITH
PULLED FODDER, CRIMSON CLOVER HAY, COWPEA-VINE HAY, CORN SILAGE, SOJA BEAN SILAGE,
AND
COTTON-SEED—RAW, ROASTED, HULLS, AND MEAL.

Publications will be sent to any address in North Carolina upon application.

N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

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DIGESTION EXPERIMENTS
WITH
PULLED FODDER, CRIMSON CLOVER HAY, COWPEA-VINE HAY, CORN SILAGE, SOJA BEAN SILAGE,
AND
COTTON-SEED—RAW, ROASTED, HULLS, AND MEAL.

BY F. E. EMERY, AGRICULTURIST, AND B. W. KILGORE, 1ST ASS'T CHEMIST.

INTRODUCTION.

Last year the first bulletin containing experiments on digestibility of cattle foods was issued. In it was recorded the work done to determine the digestibility of cotton-seed hulls alone, and of the same fed with cotton-seed meal in a ration.

A statement of how a digestion experiment is made was included with that bulletin,* and need not be repeated here.

This bulletin records another year's progress in the work of determining the true value of these distinctively Southern cattle foods, in order that they may be the better appreciated, and fed for more economical production, in a rational system, than is possible by haphazard methods without these determinations.

The digestion work accomplished and here reported, together with deductions therefrom, includes determinations on—

1. Pulled Fodder (corn leaves alone) with two animals.
2. Crimson Clover Hay with two animals.
3. Cowpea-vine Hay with two animals.
4. Soja Bean Silage with two animals.
5. Corn Silage with one animal.
6. Corn Silage and Raw Cotton-seed with one animal, duplicated.
7. Corn Silage and Roasted Cotton-seed with two animals.
8. Corn Silage and Cotton-seed Meal (ratio 12 to 1) with two animals.
9. Corn Silage and Cotton-seed Meal (ratio 8 to 1) with two animals.
10. Cotton-seed Hulls alone with three animals.
11. Cotton-seed Hulls and Cotton-seed Meal (ratio 7 to 1) with one animal.
12. Cotton-seed Hulls and Cotton-seed Meal (ratio 6 to 1) with two animals.
13. Cotton-seed Hulls and Cotton-seed Meal (ratio 4 to 1) with two animals.

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* Bulletin No. 80c. **Technical Bulletin No. 3.**

14. Digestible Organic Nutrients in one hundred pounds of dry matter of Fodder and Rations.
15. Actual *vs.* Calculated Nutritive Ratios of Rations.
16. Comparative Digestive Power of Sheep and Goats, and Cows and Goats for the same Foods.
17. The Nitrogen-free Extract of Foods.
18. Summary of Coefficients of Digestibility.
19. Conclusions.

DISCUSSION.

The Animals Employed.—In digestion experiments with large animals it is necessary to keep attendants with the animals during the time collections are being made, while with smaller animals this may be avoided by collecting the excrement in rubber-lined bags, which are attached to the animals by means of a simple harness. Sheep are more commonly used for this work, as at the Maine and Wisconsin Stations. Their wool aids in retaining the harness, and they usually take kindly to the necessary handling. The sheep of our section, however, are rather scrawny and wild, and have pined away in previously conducted experiments, hence we have thought it advisable to replace the sheep by the goat, as being better suited to bear confinement and handling, while the results should be in harmony with those from sheep, and just as applicable in the calculation of rations for neat cattle. The comparisons made between digestion of the same articles by both sheep and goats in the following pages support this view, while we have the opinions of some of the leading authorities to the effect that coefficients of digestibility obtained with the goat may be used with confidence for the calculation of rations for the other domestic ruminants, the cow and sheep.

The two sheep used in these experiments were obtained from a butcher's flock, and were rather thin in flesh but appeared to be healthy. They proved to be infested with lice, which gave some trouble by weakening the sheep and spreading to the goats.

One of the two goats was fat and the other in good store condition when received, and both had been accustomed to harness. The only difficulty with them was to keep the harness in place, which required rather more straps, and to be closer drawn than for the sheep.

Other animals used were a brindled heifer, called "Brindle," two years old, grown on the place, of the common native stock; two steers, "Lineback" and "Yellow," from Southwestern Virginia, the former evidently graded with Short-horn, while the latter had the appearance of being a native.

The Spotted Heifer and steers numbered 1, 2 and 3, were from Chatham County native cows, graded up with Jersey sires. Steers numbered 2 and 3 had a full Jersey sire. All the steers were fattening and were sold for beef.

In all cases but one the animals were fed all they would eat for at least eight days before collections were begun, and where any change was made in the amount of food allowed it was a reduction, and was made to reduce the amount of waste. This did not interfere with the amount the animal would consume. The one exception was with Lineback in a ration of cotton-seed hulls and meal, where four pounds of hulls to one pound of meal were being offered. Because of waste the morning before, and at two feeds after collections began, the feed offered the next morning was dropped one-third, to be increased with return of appetite. It was not increased until half through the period of six days, then it was returned to the former amount.

The fodders which are here subjected to digestion are those for which no previous determinations of digestibility have been made in America, so far as we know, except silage, cotton-seed hulls and a ration of hulls and meal. The digestion of silage alone was necessary to preface that of raw cotton-seed, and that of the hulls was determined for study in connection with the series of rations of cotton-seed hulls and meal begun last year and continued in these determinations.

Pulled Fodder.—This is a valuable forage, and is commonly prized, and is handy to feed out. It costs too much in the pulling and curing, and for this reason the crop should be harvested in a different way, and more than the leaves saved. It is believed by many farmers that pulled fodder (the leaves alone) costs in harvesting all that it can be sold for if prime, and much more if, by chance, it becomes damaged. The Texas Experiment Station has shown (Bulletin 19) that with their large crops, on which harvesting can be more cheaply done than in our smaller ones, the cost of pulled fodder, with labor at $1 per day for a man and $2 for man and team, to be—

Where tops alone were cured	$2.13 per ton.
Where leaves alone were cured	7.67 per ton.
Where tops and leaves together were cured	2.25 per ton.

This process is regarded as profitable in any case, but most so in the last.

This forage is saved from the corn grown for grain, and it is usually fed by the bundle, with a given number of ears of corn, per feed. A better practice, when once learned, would be, for cows, sheep, and working animals on the farm, to cure the entire plant (stalk, leaves and ears when glazing) at one operation in a silo, and feed it out, with a more nitrogenous fodder, such as clover and cowpea-vine hay, or soy bean silage, or with a by-product rich in albuminoids, like cotton-seed meal.

Waste.—The total waste for each animal in all the experiments was kept, dried when necessary, and mixed at the end of the digestion for the sample for analysis.

1. DIGESTION OF PULLED FODDER (CURED CORN LEAVES) BY ONE SHEEP AND ONE GOAT.

Date of Experiment. October, 1891.

Preliminary Period.—The horned sheep and black goat were fed this ration 19 and 20 days respectively before collections were begun. They gained some weight, which appeared to be due, in part at least, to more water drank during the later feeding than at first, and drinking at night instead of morning after weights were taken.

The sheep ate 789.3 grams of fodder, drank 1546.8 grams of water per day, and averaged 63 pounds in weight during the first 10 days and 67 pounds during the second 10 days.

The black goat ate 843.7 grams of fodder, drank 807.4 grams of water daily during this period, and weighed during the first 10 days 102.5 pounds, second 10 days 104.6 pounds.

During the Collection Period of six days the sheep ate 807.4 grams of fodder, drank 1378.9 grams of water daily, and weighed an average of 66.7 pounds. The goat ate 907.2 grams of fodder, drank 1111.3 grams of water daily, and weighed 108 pounds.

The fodder fed was all cut at once, well mixed, and kept in large bags. The sample for analysis was taken from the mixture.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. These data are more conveniently seen and studied by reference to Tables I and II.

TABLE I. ·Showing Percentage Composition of Corn Fodder, Waste, and Solid Excrement.

	Water	Dry Matter.	DRY MATTER CONTAINS							
			Ash,	Protein (N×6.25)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct	Crude Fiber.	Total Sugr's	Starch.
Corn Fodder fed	10.72	89.28	8.08	10.76	9.19	4.43	51.13	25.60	3.91	24.67
Corn Fodder waste—Black Goat	10,74	89.26	7.21	5.81	4.90	2.66	50.43	33.89	3.20	25.20
" " " —Horned Sheep	10.71	89.29	7.23	11.51	6.44	3.24	49.32	28.62	4.66	19.62
Solid Excrement—Black Goat	57.33	42.67	15.66	8.64	8.64	3.87	48.83	23.00	----	19.82
" " —Horned Sheep	80.76	19.24	17.01	13.62	13.62	4.38	46.55	18.44	. --	18.19

TABLE II. Showing Nutrients Consumed and Excreted in Grams,* with Percentages Digested.

BLACK GOAT.

	Total Dry Matter	DRY MATTER CONTAINS								
		Ash.	Protein (N×6.25)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Sug'rs	Starcl	Undetermined Carbohydrates
Fed in Pulled Fodder	6428.2	519.4	691 7	590.8	284.8	3286 7	1645.6	251.34	1585.84	1449.52
Waste in Pulled Fodder	1663.4	119.9	96.6	81.5	44.2	838.9	563.7	53.22	419.18	366.50
Total consumed	4764.8	399.5	595.1	509.3	240 6	2447.8	1081.9	198 12	1166.66	1083.02
Excreted in Dung	2151.1	336.9	185.9	785.9	83.2	1050.3	494.7	-----	426.34	623.96
Total Digested	2613.7	62.6	409.2	323.4	157.4	1397.5	587.2	198.12	740.32	459.06
Per cent. Digested	54.85	15.67	68.76	63.50	65.42	57.08	54.27	100.00	63.45	42.38

HORNED SHEEP.

	Total Dry Matter	Ash.	Protein (N×6.25)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Sug'rs	Starcl	Undetermined Carbohydrates
Fed in Pulled Fodder	5916.8	478.1	636.6	543.8	262.1	3025.3	1514.7	231.35	1459.68	1334.27
Waste in Pulled Fodder	1588.6	114.8	182.8	102.3	51.5	784.2	454.6	74.03	311.68	398.49
Total consumed	4328.2	363 3	453.8	441.5	210.6	2241.1	1060.1	157.32	1148.00	935 78
Excreted in Dung	1894.6	322.3	258.0	258.0	83 0	881.9	349.4	-----	344.63	537.27
Total Digested	2433.6	41.0	195.8	183.5	127.6	1359.2	710.7	157.32	803.37	398.51
Per cent. Digested	56.22	11.29	43.15	41 56	60 59	60.65	67.04	100.00	69.98	42.59
Average per cent. Digested	55.53	13.48	55 95	52.53	63.00	58.86	60.65	100.00	66.71	42.48

Mean nutritive ratio of Corn Fodder, 1: 8.73.

*One gram equals 15.43 grains. One ounce equals 28.35 grams. One pound equals 453.59 grams.

The above coefficients show corn fodder to be superior in feeding value to timothy or red-top, and almost equal to clover hay.

A ration for a 1,000-pound horse or mule would be 5 or 6 bundles of fodder with 21 ears of corn per day for light work. This ration compares with the standard about as follows:

	Total Wght Lbs.	Dry Matt'r Lbs.	Pro-tein. Lbs.	Carbo-hydrates. Lbs.	Fats Lbs	Nutritive Substance Lbs.	Ratio. 1 to
5 or 6 bundles fodder	10.	8.93	.60	4.54	.30	5.44	------
21 good ears of corn	14.	12.52	1.04	8.72	.35	10.11	------
	24.	21.45	1.64	13.26	.65	15.55	9.2
German standard	------	22.5*	1.80	11.2	.60	13.6	7.00

For horses and mules fodder is a little too bulky to be fed alone, but for working steers it makes a very good ration when fed alone. It differs from the standard by a small excess of carbohydrates and fat, which widens the ratio, but then it is nearer the standard than when fed with corn.

	Total Wght Lbs.	Dry Matt'r Lbs.	Pro-tein. Lbs.	Carbo-hydrates. Lbs.	Fats Lbs	Nutritive Substance Lbs.	Ratio. 1:
Fodder (cured corn leaves)	25.	22.33	1.50	11.35	.75	13.60	8.73
German standard for moderate work	------	24.*	1.60	11.3	.30	13.20	7.5

2. DIGESTION OF CRIMSON CLOVER HAY

BY ONE GOAT AND ONE SHEEP.

Date of Experiment, November, 1891.

The Preliminary Period for the gray goat was 8 days, and for the hornless sheep 8 days. The goat ate 771.1 grams of hay daily. The sheep ate 399.2 grams of hay per day.

During the Collection Period of 6 days the goat ate 811.9 grams of hay and drank 1129.5 grams of water daily. The sheep ate 403.7 grams and drank 621.4 grams water per day.

The goat weighed one-fourth pound less at the end of the collection period than the average for the 8 preceding days, while the sheep fell off from an average of 53 pounds to 49 pounds at the close of the collection period. The clover hay fed was prepared the same as the corn fodder. An aliquot sample was taken at each feed and preserved in air-tight jars till ready to anlayze.

Analytical and Other Data for Obtaining the Coefficiency of Digestibility. See Tables III and IV.

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*Organic matter.

TABLE III. SHOWING PERCENTAGE COMPOSITION CRIMSON CLOVER, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext)	N.-Free Extr'ct.	Crude Fiber.	Total Sugars.	St'rch
Crimson clover hay	10.85	89.15	9.20	18.01	14.02	2.57	41.67	28.55	2.67	11.14
Waste, crimson clover hay—Gray Goat	10.58	89.42	10.63	19.50	15.65	2.81	39.18	27.88	2.32	10.02
" " —Hornless Sheep	10.83	89.17	9.89	21.73	16.96	2.60	41.07	24.71	2.33	9.95
Solid excrement—Gray Goat	58.43	41.57	10 39	13.86	13 86	3.53	31.70	40.52	....	9.53
" " —Hornless Sheep	53 77	46.23	11.75	14.02	14.02	3.38	31.60	39.25	....	9.81

TABLE IV. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN GRAMS, WITH PERCENTAGES DIGESTED.

GRAY GOAT.

	Total Am'nt.	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N -Free Extr'ct.	Crude Fiber.	Total Sug'rs	St'rch	Undetermined Carbohydrates
Crimson clover hay fed	5400.	4814.1	442.9	867.0	674 9	123.7	2006.0	1374.4	128.54	536.29	1341.17
" " waste	518.	463.2	49.2	90.3	72.5	13.0	181.5	129.1	10.75	46.41	124.33
Total consumed	4882.0	4350.9	393.7	776 7	602.4	110.7	1824.5	1245.3	117.79	489 88	1216.84
Total solid excrement	4245.5	1764.8	183.3	244.6	244.6	62.3	559.4	715.1	......	168.19	391.21
Total digested	......	2586.1	210.4	532.1	357.8	48.4	1265 1	530.2	117.79	321.69	825 63
Per cent. digested	......	59.44	53.44	68.52	59.39	43.72	69 34	42.57	100.00	65.66	67.85

HORNLESS SHEEP.

	Total Am'nt.	Dry Matter.	Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N -Free Extr'ct.	Crude Fiber.	Total Sug'rs	St'rch	Undetermined Carbohydrates
Crimson clover hay fed	3600.0	3209.4	295.2	578.0	449.9	82.8	1337.3	916.3	85 69	357.53	894 08
" " waste	1173.0	1046.0	103.4	227.3	177.4	27.2	429.6	258.5	24 37	104.08	301.15
Total consumed	2427 0	216 43	191.8	350.7	272 5	55.6	907.7	657.8	61.32	253.45	592.93
Total solid excrement	1638.0	757.2	88.9	106.1	106.1	25.6	239.3	297.2	......	74.28	165.02
Total digested	......	1406.2	102.9	244.6	166.4	30.0	668.4	360.6	61.32	179 17	427.91
Per cent. digested	......	65.00	53.65	69 75	61.06	53.96	73.63	54.82	100.00	70.67	72,17
Average per cent. digested	.....	62.22	53.55	69.14	60.23	48.83	71.49	48.70	100.00	68.16	70.01

Mean nutritive ratio of crimson clover hay, 1: 3.76.

The composition of crimson clover hay and the coefficients of its digestibility show it to be a highly nutritious food. To bring out more clearly its nutritive value comparison is made below with other well known and highly prized leguminous plants in a table showing the actual amounts of digestible nutrients in one hundred pounds of dry matter of each.

	Protein.	Carbohydrates	Fats.	Ratio. 1 to
Alfalfa hay, average of O'Brine* and N. Y. Ag. Ex. Station†	10.55	44 31	1.35	4.52
Alsike clover hay—Jordan‡	9.31	46.96	2.76	5.78
Red clover hay—Armsby§	6 64	42.64	0.80	6.72
Crimson clover hay (this experiment)	12.45	43.70	1.25	3.76

Scarlet clover (Trifolium incarnatum) is known under a variety of common names—Annual, German, Scarlet and Italian. This clover is easily grown, and should come into quite general use. It is an annual, and consequently must be re-seeded for each crop, which makes it important to grow seed at home. Seed may be sown from July to October, but the land should always be well prepared for it, or, if not, it should be well shaded, as under a good growth of cowpeavines, or in a corn or cotton crop, when the seed should be sown when the crop is laid by. Grown in this way it may be of great service in enriching and holding the land from washing. Its growth is made in the cool wet part of the year, and it is ready to be made into hay at a season when planters are waiting for cotton to vegetate for first working. This is often a dry time, and the hay can be quickly and easily cured. It may often be best to sow this clover with oats, rye or barley, and cut all for hay in April or May, as above.

This clover will thrive on land in moderate condition, but, like some other forage plants, will pay best where given a rich soil.

The high protein content, large proportion of amides and narrow ratio are especially noticeable in this hay. It is so rich that for any use it may well be fed with some such fodder as straw, meadow hay, or cotton-seed hulls. When fed for production of milk, the addition of corn, or corn and oats, will tend to widen the ratio, and probably add to the good qualities of the product.

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*Bulletin No. 8, Col. Ag. Exp't Sta.

†Eighth Annual Report, p. 143.

‡Maine Ag. Exp't Sta., Ann. Rep. 1889, part 2.

§Univ. of Wisc., Ag. Ex. Sta. Bulletin No. 3.

3. DIGESTION OF COWPEA-VINE HAY

By Black Goat and Horned Sheep.

Date of Experiment, November, 1891.

Preliminary Period. During this period of 8 days there were eaten 779.6 and 654.6 grams of hay, and drank 1860. and 2481. grams of water by goat and sheep respectively. Their weights at close were 104 and 65 pounds respectively.

Collection Period was of 6 days. There was eaten 816.7 and 562.3 grams by the goat and sheep, and they drank 2003. and 2112. grams of water respectively. Weights at close were 103 and 60 pounds respectively. These differences in weight were doubtless part due to larger drinks of water at night before weights were taken than before the last weights.

The above hay was prepared for feeding the same as the corn fodder and crimson clover. The sample for analysis was taken from the mixture.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables V and VI.

TABLE V. SHOWING PERCENTAGE COMPOSITION OF COWPEA-VINE HAY, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter	DRY MATTER CONTAINS Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth.Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars.	St'rch
Cowpea-vine hay	11.26	88.74	5 36	14.24	9.45	1.50	45.57	33.33	4.43	16.44
Waste cowpea-vine hay—Black Goat	13.91	86.09	5.55	13.11	8.22	1.13	43.35	36.86	4.58	17.40
" " —Horned Sheep	17.26	82.74	5.61	14.16	8.96	1.21	42.09	36 93	4.44	16.50
Solid excrement—Black Goat	54.92	45.08	5.98	12 59	12.59	1.88	33.56	45.99	....	15 02
" —Horned Sheep	66.06	33.94	8.21	12 61	12.61	2.11	33.62	43.45	....	13.88

TABLE VI. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN GRAMS, WITH PERCENTAGES DIGESTED.

BLACK GOAT.

	Total Am't	Dry Matter	DRY MATTER CONTAINS. Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.	Undet'm'n'd Carb'hyd'tes
Cowpea-vine hay fed	7017.0	6226.9	333.8	886.7	588.4	93 4	2837.6	2075.4	275 85	1023.70	1538.05
" " waste	2116.5	1822.0	101.1	238.9	149.8	20.6	789.8	671.6	83.45	317.03	389.32
Total consumed	......	4404 9	232.7	647.8	438.6	72.8	2047.8	1403.8	192.40	706 67	1148.73
" solid excrement	3979.	1793.6	107.3	225.8	225.8	33.7	601.9	824.9	.....	269.40	332.50
" digested	......	2611.3	125.4	422.0	212.8	39 1	1445 9	578.9	192.40	437.27	816.23
Per cent. digested	......	59.28	53.89	65.14	48.52	53.71	70.61	41.24	100.00	61.88	71.05

HORNED SHEEP.

	Total Am't	Dry Matter	Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.	Undet'm'n'd Carb'hyd'tes
Cowpea-vine hay fed	4740.2	4206.5	225.5	599.0	397.5	63.1	1916.9	1402.0	186 35	691.55	1039.00
" " waste	1366.	1130.2	63.4	160.0	101.3	13.7	475.7	417.4	50.18	186.48	239.04
Total consumed	......	3076.3	162.1	439.0	296.2	49.4	1441.2	984.6	136.17	505.07	799.96
" solid excrement	3700.	1255.6	103.1	158.3	158.3	26.5	422.1	545.6	......	174.28	247.82
" digested	......	1820.7	59.0	280.7	137.9	22.9	1019.1	439.0	136.17	330.79	552.14
Per cent. digested	......	59.18	36.40	63.94	46.56	46.36	70.71	44.59	100.00	65.49	69.02
Average per cent. digested	......	59.2	45.1	64.5	47.5	50.0	70.7	42.9	100.00	63.68	70.03

Mean nutritive ratio of cowpea-vine hay, 1: 5.27.

Wet weather set in and continued for a week with heavy fall of rain at the time our peavines were ready to cut for hay. This delayed the hay-making so long that the leaves were fast falling and the coarse stems too ripe for good hay, but by carefully selecting what was needed for this experiment it was hoped to secure what would represent an average quality. How near this was attained can only be determined by comparison with other analyses, which show this hay to be low in content of ash, protein and fat, and to have a greater amount of crude fiber than some other analyses show.*

However, the nutritive ratio obtained in this experiment shows this hay to have been relatively about equal to the standard rations for heavy work and production of milk. Its fitness for these uses would depend much on its palatability. These animals ate this hay nearly as well as they did the pulled fodder and the clover. With cowpea-vine hay of good quality for above uses, no grain need be used, while for maintenance and light work straw or cotton-seed hulls could well be fed as a part of a good ration.

4. DIGESTION OF SOJA (SOY) BEAN SILAGE

By Black and Gray Goats.

Date of Experiment, March and April, 1892.

Daily ration, 2721.6 grams (6 pounds) per day. Total period, 40 days. Feces collected last 5 days.

This silage was being fed to a herd of cows, and was taken fresh from the silo for every feed after cows were fed. Every second day during the collection period samples of the silage were taken for analysis.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables VII and VIII.

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*Report Conn. Exp't Sta. 1887, p. 185.

TABLE VII. Showing Percentage Composition of Soja Bean Silage, Waste, and Solid Excrement.

	Moisture.	Dry Matter	DRY MATTER COTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.
Soja bean silage	74.20	25.80	11.02	15.71	11.42	8.66	26.96	37.65	1.66	16.59
Waste, soja bean silage—Black Goat	70.18	29.82	10.61	15.42	13.37	8.66	28.55	36.76	1.42	13.65
" " " —Gray Goat	73.20	26.80	9.85	16.43	12.50	9.43	30.72	33.57	1.46	13.29
Solid excrement—Black Goat	51.83	48.17	12.25	9.45	9.45	6.09	30.44	41.77	----	12.93
" —Gray Goat	49.08	50.92	11.37	8.89	8.89	5.51	30.86	43.37	----	13.98

TABLE VIII. Showing Nutrients Consumed and Excreted in Grams, with Percentages Digested.

BLACK GOAT.

	Total Am't	Total Dry Matter	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars	Starch.	Undetermined Carbohydrates
Soja bean silage fed	13607.7	3510.8	386.9	551.5	400.9	304.0	946.5	1321.8	58.28	582.44	305.78
" " waste	731.0	218.0	23.1	33.6	29.1	18.9	62.2	80.1	3.10	29.76	29.34
Total consumed	12876.7	3292.8	363.8	517.9	371.8	285.1	884.3	1241.7	55.18	552.68	276.44
" solid excrement	3263.0	1571.8	192.5	148.5	148.5	95.7	478.5	656.5	----	203.23	275.27
" digested	9613.7	1721.0	171.3	369.4	223.3	189.4	405.8	585.2	55.18	349.45	1.17
Per cent. digested	------	52.26	47.09	71.31	60.06	66.43	45.88	47.13	100.00	63.23	.42

GRAY GOAT.

	Total Am't	Total Dry Matter	Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars	Starch.	Undetermined Carbohydrates
Soja bean silage fed	13607.7	3510.8	386.9	551.5	400.9	304.0	946.5	1321.8	58.28	582.44	305.78
" " waste	4131.0	1107.2	109.1	181.9	138.1	104.4	340.1	371.7	16.17	147.15	176.78
Total consumed	9476.7	2403.6	277.8	369.6	262.8	199.6	606.4	950.1	42.11	435.29	129.00
" solid excrement	1614.5	822.2	93.5	73.2	73.2	45.3	253.7	356.6	-----	114.94	138.76
" digested	7862.2	1581.4	184.3	296.4	189.6	154.3	352.7	593.5	42.11	320.35	—9.76
Per cent. digested	-------	65.79	66.34	80.19	72.15	77.30	58.16	62.47	100.00	73.59	------
Average per cent. digested	------	59.02	56.71	75.75	66.10	71.86	52.02	54.80	100.00	68.41	------

Mean nutritive ratio of soja bean silage, 1: 4.22.

The soja bean is one of our most promising crops. Soja bean silage has been fed in our stable long enough to give assurance of its value. For milch cows it has seemed to arrest the natural decline in yield for a time, when fed after a long period on corn silage. This may have been partly due to other causes, as changes in grain fed, and approach of spring. Fed to a bull of a little under 1,000 pounds weight for over five weeks, at the rate of 45 pounds per day, 44 8 pounds were consumed, and the bull made a slow but steady gain in weight.

The high percentage of protein in proportion to carbohydrates gives this silage a narrow nutritive ratio, and this indicates that it can be used to good advantage as part of a ration of hay or straw with corn, or corn and oats, or mixed with corn silage. Indeed, we have a correspondent who is growing corn and soja beans together for silage, and who assures us that this combination saves him much grain, as less is needed with his stock when feeding this combination than with other coarse foods.

A ration of 40 pounds corn and soy bean silage in equal parts by weight as good as digested in this and Experiment 5 has been calculated to yield digestible nutrients in pounds as follows: protein, .768; fats, .418; other carbohydrates, 4.622. The nutritive ratio is 1 to 7.4, and although the nutritive substance is but 5.81 pounds, less than two-thirds of the standard for oxen at rest, it is, in all probability, sufficient to sustain a 1,000-pound animal and produce slow gain. This is possible because the animal will take little or no water not in the silage, and having, therefore, less internal work to perform, the small amount of nutritive substance suffices for the animal's needs.*

5. DIGESTION OF CORN SILAGE

By Brindle Cow.

Date of Experiment, January and February, 1892.

Ration fed, silage *ad libitum.*

Total period, 17 days, which included three or four days recovering from exclusive cotton-seed diet.

Feces collected last 6 days.

Samples were taken every two days of collection period, taking about four pounds each time. These samples were dried, mixed and ground for analysis. This silage was from the College farm, where the yield per acre was light.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See following Tables IX and X.

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* For further explanation of sustenance on small ration see Armsby's Manual of Cattle Feeding, pp. 381–2.

TABLE IX. SHOWING PERCENTAGE COMPOSITION OF CORN SILAGE, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter	DRY MATTER CONTAINS							
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars	Starch.
Corn silage	70.27	29 73	4.12	7 52	6.73	2.47	60.88	25.01	2.63	25.49
Waste silage	60.33	39.67	5.77	7.95	7.16	1.78	53.98	30.52	1.53	20.83
Solid excrement	79.97	20.03	6 13	10.46	10:46	1.85	52.00	29.56	....	24.94

TABLE X. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

	Total Am't	Dry Matter	DRY MATTER CONTAINS								
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars	Starch.	Undetermined Carbohydrates
Corn silage fed	2048.	608.87	25.09	45.79	40.98	15.04	370.68	152.28	16.01	155.20	199.47
Waste corn silage	159.75	64.37	3.71	5.12	4.61	1.14	34.75	19.65	.98	13.41	20.36
Total consumed	1888.25	544.50	21 38	40.67	36.37	13.90	335.93	132.63	15.03	141.79	179.11
" solid excrement	1273.	254.98	15.63	26 67	26.67	4.72	132.59	75.37	.....	63.59	69.00
" digested	....	289.52	5.75	14.00	9.60	9 18	203.34	57.26	15 03	78.20	110.11
Per cent. digested	....	53.17	26.89	34.41	26.39	66.04	60.53	43.17	100.00	55.16	61.43

Nutritive ratio of corn silage, 1: 19.96.

The nutritive ratio of this silage is rather wide. Its digestibility was determined to preface those of raw and roasted cotton-seed, which could not be fed alone, and also to use in a study of the digestibility of rations of cotton seed meal and corn silage, which follow.

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6. DIGESTION OF RAW COTTON-SEED AND SILAGE

By Brindle Cow.

Date of First Experiment, February, 1892.

Daily ration, 12 pounds silage, 4½ pounds raw cotton-seed.

Total period, 21 days, 13 days after proportions of seed and silage were settled.

Feces collected, last 6 days.

The sample of silage for analysis was taken and treated the same as for first determination. Two ounces of cotton-seed were put into an air-tight jar at each feed for samples to be analysed.

Date of Second Experiment, February and March, 1892.

Ration, same as above.

Feces collected for 6 days, with only one day intervening between above first experiment and second.

Samples taken for silage, same as above.

An attempt was made to determine digestibility of raw seed directly, when it was found that the heifer would eat enough seed to support life, but after eight days the physical effect of the seed was too great, and the heifer stopped eating. Following this, silage was substituted, and the determination on silage made to precede that of silage and raw seed.

Analytical and Other Data for Calculating the Coefficients of Digestibility. See Tables XI and XII.

TABLE XI. Showing Percentage Composition of Raw Cotton-seed, Corn Silage, Waste, and Solid Excrement.

	Moisture.	Dry Matter.	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Raw cotton-seed	17.51	82.49	3.52	17.56	17.56	23.49	30.82	24.61	.62	13.34
Corn silage—1st experiment	73.01	26.99	4.19	7.58	5.82	2.49	63.85	21.89	3.06	25.63
Corn silage—2d experiment	72.67	27.33	4.16	7.49	5.31	2.62	49,99	35.74	3.71	26.51
Waste raw cotton-seed and silage—2d experiment	49.52	50.48	3.30	15.28	14.76	17.27	33.27	30.88	.73	15.74
Solid excrement—1st experiment	75 52	24.48	6.28	13.42	13.42	5.30	54.98	20.02	....	18.39
Solid excrement—2d experiment	75.31	24 69	6.21	13.19	13.19	4.81	41.89	33.90	....	17.85

TABLE XII. Showing Nutrients Consumed and Excreted in Ounces, with Percentages Digested.

FIRST EXPERIMENT.

	Total Amount	Total Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Raw cotton-seed fed	432 0	356.40	12.54	62.58	62.58	83.72	109.84	87.71	2.21	47.54	60.09
Corn silage fed	1152.0	310.92	13.03	23.56	18.09	7.74	198.52	68.06	9.51	79.69	109.32
Total consumed	1584.00	667.32	25.57	86.14	80.67	91.46	308 36	155.77	11.72	127.23	169.41
Total solid excrement	1041.50	254.95	16.01	34.21	34.21	13.51	140.17	51.04	....	46.88	93.29
Total digested	542.50	412.37	9.56	51.93	46.46	77.95	168.19	104.73	11.72	80.35	76.12
Digested fr'm corn silage	....	165.32	3.50	8.11	4.77	5.11	114.11	29 38	9.51	43.96	67.15
" raw cotton-seed	....	247.05	6.06	43.82	41.69	72.84	54.08	75.35	2.21	36.39	8.97
Per ct. of ration digested	....	61.79	37.35	60.29	57.59	85.22	54.54	67.23	100.00	63.15	44.92
Pr ct. of raw cotton-seed digested	....	69.31	48.32	70.02	66.62	87.00	49.23	85.91	100.00	76.54	14.92

TABLE XII—CONTINUED.

SECOND EXPERIMENT.

	Total Amo'nt.	Total Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25)	Fats. (Eth. Ext.)	N-Free Extr'ct	Crude Fiber.	Total Sugars.	Starch.	Undet'rmin'd Carb'hydr'tes
Raw cotton-seed fed	432.00	356 40	12.54	62.58	62.58	83.72	109.84	87.71	2.21	47.54	60.09
Corn silage fed	1152 00	314.84	13.10	23.58	16.72	8.25	157.39	112.52	11.68	83.46	62.25
Total fed	1584.00	671.24	25.64	86.16	79.30	91.97	267.23	200.23	13.89	131.00	122 34
Waste raw cotton-seed and silage*	30.63	15.46	.51	2 36	2.28	2.67	5.14	4.77	.11	2.43	2.60
Total consumed	1553.37	655.78	25.13	83.80	77.02	89.30	262.09	195.46	13.78	128.57	119.74
" solid excrement	1108.00	273.56	16.99	36.08	36.08	13.16	114.59	92.74	......	48.83	65.76
" digested	445.37	382.22	8.14	47.72	40.94	76 14	147.50	102.72	13.78	79.74	53.98
Digested from corn silage	....	166.24	3.50	8.06	4.39	5.41	94.60	48.24	11.68	46.03	38.24
Digested from raw cotton seed	... ...	215.98	4.64	39.66	36.55	70.73	52.90	54.48	2.10	33.71	15.74
Per cent. of ration digested	....	58.29	32.39	56.94	53.16	85 26	56.28	52.55	100.00	62.02	45.08
Per cent. of raw cotton-seed digested	....	62.94	38.28	65.68	60.49	87.20	50.00	65.07	100.00	74.73	27.37
Average per cent. of ration digested	....	60.04	34.87	58.61	55.37	85.44	55.41	59.89	100.00	62.58	45.03
Average per cent. of raw cotton-seed digested	......	66.14	43.30	67.85	63.55	87.10	49.61	75.49	100.00	75.63	21.14

Mean nutritive ratio of ration, 1 lb. raw cotton-seed to 2.66 lbs. corn silage; or on dry matter basis, 1 lb. raw cotton-seed to .88 lb. corn silage, 1: 9.12.

Mean nutritive ration of raw cotton-seed in above ration, 1: 7.13.

*The waste raw cotton-seed and silage was composed of 8 ozs. silage and 22⅝ ozs. raw seed. They were analyzed together, but in calculating the coefficients for raw cotton-seed, amounts of nutrients corresponding to the foregoing quantities of silage and seed were taken out.

In the above table are given the coefficients of digestibility of the ration of silage and raw cotton-seed, and also of the raw cotton-seed alone, calculated by using the coefficients obtained with the same animal for corn silage in preceding experiment. The animal could not thrive upon raw cotton-seed alone, and it was necessary to feed with them silage or some other like food whose digestibility was known. The cofficients make a good showing for raw cotton-seed, especially so when we consider the low digestibility of the hulls, which compose about one-half the whole seed. The high digestibility of the starch and low digestibility of the gums, wax, and other undetermined carbohydrates of raw cotton-seed, as well as those of the roasted seed, are points interesting to note.

7. DIGESTION OF ROASTED COTTON-SEED AND SILAGE

By Spotted Heifer and Steer No. 3.

Date of Experiment, February and March, 1892.

Total period, 15 days.

Daily ration, 12 pounds silage and 6 pounds roasted seed.

Feces collected during last six days.

Equal samples of roasted seed were taken at every feed and preserved in air-tight jars till ready for analysis.

The silage fed in this experiment was the same as in the second experiment with raw seed and silage.

The seed were roasted in a Greene roaster, which is a wire-covered cylinder revolving in a sheet-iron frame. The seed lost in roasting 17.66 per cent. of their original weight. There was 17.51 per cent. water in the fresh seed. The loss was, therefore, mainly water driven off.

The roasted seed had a pleasant odor and taste, and were quite palatable, except for a slight bitterness of the browned hull residue after being chewed.

Analytical and Other Data for Calculating the Coefficients of Digestibility. See Tables XIII and XIV.

TABLE XIII. SHOWING PERCENTAGE COMPOSITION OF ROASTED COTTON-SEED, CORN SILAGE, WASTE, AND SOLID EXCREMENT.

	Moisture.	Dry Matter.	DRY MATTER CONTAINS Ash.	Protein. (N×6.25)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Roasted cotton-seed	9.32	90.68	2.50	17.75	17.75	24 80	28.44	26.51	.94	15 70
Corn silage	72.67	27.33	4.16	7.49	5.31	2.62	49.99	35.74	3.71	26.51
Waste roast cot.-seed—Spotted Heifer	16.25	83.75	4 19	18.26	17.05	25.44	27.52	24.59	.91	13.53
" " —Steer No. 3	18 07	81.93	3.64	18.02	16.35	24.07	26.25	28.02	.91	15 05
Solid excrement—Spotted Heifer	76.45	23.55	6.28	15.53	15.53	7.95	37.72	32.52	----	17.68
" " —Steer No. 3	75.71	24.29	5.61	15.77	15.77	9.52	37.16	31.94	---	16.47

TABLE XIV. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

SPOTTED HEIFER.

	Total Amount	Dry Matter.	DRY MATTER CONTAINS Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sug'rs	Starch.	Undetermined Carbohydrates
Roasted cotton-seed fed	576 00	522.32	13 06	92.71	92.71	129.54	148.55	138.47	4.91	82.00	61.64
Corn silage fed	1152.00	314.84	13.10	23.58	16.72	8.25	157.39	112.52	11.68	83.46	62.25
Total fed	1728.00	837.16	26 16	116 29	109.43	137.79	305.94	250.99	16 59	165.46	123.89
Waste roasted cot.-seed	243 00	203.51	8.53	37.16	34.70	51.77	56 00	50 04	1.85	27.54	26.61
Total consumed	1485.00	633.65	17.63	79.13	74.73	86.02	249.94	200.95	14.74	137.92	97.28
" solid excrement	1189.25	280.07	17 59	43 49	43.49	22.26	105.64	91.08	------	49.52	56.12
" digested	295.75	353.58	0.04	35.64	31.24	63.76	144.30	109.87	14.74	88 40	41.16
Digested fr'm corn silage	--------	167.40	3.52	8.11	4.41	5.45	95.26	48.57	11.68	46.03	38.24
" from roasted cotton-seed	--------	186.18	-----	27.53	26.83	58.31	49.04	61.30	3.06	42.37	2.92
Per cent. of ration digested	--------	55.80	0.22	45.04	41.80	74.12	57.73	54.67	100.00	64.09	42.31
Per cent. of roasted cotton-seed digested	--------	58.40	-----	49.56	46.25	74.95	52.99	69.32	100.00	77.80	8.34

TABLE XIV.—CONTINUED.

STEER No. 3.

	Total Amount	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sug'rs	Starch.	Undetermined Carbohydrates
Roasted cotton-seed fed	576.00	522.32	13.06	92 71	92.71	129.54	148.55	138.47	4.91	82.00	61.64
Corn silage fed	1152 00	314.84	13.10	23.58	16.72	8.25	157.39	112.52	11.68	83 46	62.25
Total fed	1728.00	837.16	26.16	116.29	109.43	137.79	305.94	250.99	16.59	165.46	123 89
Waste roasted cot.-seed	248 63	203.70	7.41	36 71	33 30	49.03	53.47	57.08	1.85	30.66	20.96
Total consumed	1479.37	633 46	18.75	79.58	76.13	88.76	252.47	193.91	14.74	134.80	102.93
" solid excrement	1217.50	295.73	16 59	46.64	46.64	28.15	109 89	94.46	------	48.71	61.18
" digested	261.87	337.73	2.16	32.94	29.49	60 61	142.58	99.45	14.74	86.09	41.75
Digested from corn silage	-------	167.40	3.52	8.11	4.41	5.45	95.26	48.57	11.68	46.03	38.24
Digested from roasted cotton-seed	-------	170.33	----	24.83	25.08	55.16	47.32	50.88	3.06	40.06	3.51
Per cent. of ration digested	-------	53.31	11.52	41.39	38.73	68.28	56.46	51.28	100.00	63.86	40.56
Per cent of roasted cotton-seed digested	-------	53.46	-----	44.34	42.21	68.51	49.77	62.51	100.00	78.03	8.62
Average per cent. of rations digested	-------	54.55	5.87	43.21	40.26	71.20	57.09	52.97	100.00	63.97	41.43
Average per ct. roasted cotton-seed digested	-------	55.93	-----	46 95	44.23	71.73	51.38	65.91	100.00	77.91	8.48

Mean nutritive ratio of ration of 1 pound roasted cotton-seed to 2 pounds corn silage, or on dry matter basis, 1 pound roasted cotton-seed to .60 pounds corn silage, 1: 11.77.

Mean nutritive ratio of roasted cotton-seed in above ration, 1: 9.19.

This table contains like data for the ration of roasted cotton-seed and silage, and for the roasted cotton-seed alone, that the preceding one does for the ration of raw seed and silage, and for raw seed alone. Comparison of the digestibility of raw cotton-seed with that of roasted cotton-seed shows the dry matter of the roasted seed to be 10 per cent. less digestible, the protein 21 per cent., albuminoids 19 per cent., fats 15 per cent., and fiber 9.5 per cent., while the nitrogen-free extract is 1.7 per cent. more digestible in the roasted than in the raw seed. The analyses of raw and roasted seed reveal little difference in the composition of the two, beyond a slight increase in fat and fiber in roasted over raw seed, and a decrease in nitrogen-free extract. These experiments show a clear and heavy loss of digestible material from roasting, to say nothing of the increased cost of roasting the seed.

8. DIGESTION OF RATION OF CORN SILAGE AND COTTON-SEED MEAL

BY GOATS.

Date of Experiment, January and February, 1892.

Daily ration, 2041.2 grams silage, equal to 72 ounces, and 170.1 grams cotton-seed meal, equal to 6 ounces.

Total period, 14 days.

Feces collected, last 6 days.

Samples of silage were the same as given in *digestion of silage* by Brindle Cow.

Cotton-seed meal was sampled by dropping a one-ounce sample of meal fed into a glass jar every time the feed was weighed out. The jar was kept tightly closed between the time of weighing.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables XV and XVI.

TABLE XV. SHOWING PERCENTAGE COMPOSITION OF CORN SILAGE, COTTON-SEED MEAL, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter.	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Corn silage fed	70.29	29.73	4.12	7.52	6.73	2.47	60.88	25.01	2.63	25.49
Cotton-seed meal fed	7.71	92.29	7.19	41.04	39.82	12.00	33.67	6.10	.94	8.08
Waste silage and cotton-seed meal—Black Goat	66.27	33.73	5.00	10.77	9.50	2.81	51.38	30.04	1.21	19.26
Waste silage and cotton-seed meal—Gray Goat	66.38	33.62	5.07	11.65	10.21	3.57	57.49	22.22	1.46	21.87
Solid excrement—Gray Goat	66.13	33.87	10.99	14.10	14.10	1.94	48.73	24.24	....	17.55
" " —Black Goat	67.02	32.98	10.87	15.53	15.53	1.80	47.97	23.83	....	17.77

TABLE XVI. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

BLACK GOAT.

	Total Amo'nt.	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Corn silage fed	432.	128.43	5.29	9.64	8.64	3.17	78.19	32.12	3.38	32.74	42.07
Cotton seed meal fed.	36.	33.22	2.39	13.63	13.23	3.99	11.18	2.03	.31	2.69	8.18
Total fed	468.	161.65	7.68	23.27	21.87	7.16	89.37	34.15	3.69	35.43	50.25
Waste silage and meal	59.	19.90	.99	2.14	1.89	0.56	10.22	5.98	.14	3.83	6.25
Total consumed	409.	141.75	6.69	21.13	19.98	6.60	79.15	28.17	3.55	31.60	44.00
" solid excrement	158.44	52.25	5.68	8.11	8.11	0.94	25.06	12.45	...	9.28	15.78
" digested	......	89.50	1.01	13.02	11.87	5.66	54.09	15.72	3.55	22.32	28.22
Per cent. digested	......	63.14	15.09	61.62	59.41	85.76	68.34	55.80	100.00	70.63	64.14

TABLE XVI—CONTINUED.

GRAY GOAT.

	Total Amo'nt.	Dry Matter.	DRY MATTER CONTAINS.								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.	Undet'rmin'd Carb'hydr'tes
Corn silage fed	432.	128.43	5.29	9.64	8.64	3.17	78.19	32.12	3.38	32.74	42.07
Cotton-seed meal fed	36.	33.22	2.39	13.63	13.23	3.99	11.18	2.03	.31	2.69	8.18
Total fed	468.	161.65	7.68	23.27	21.87	7.16	89.37	34.15	3.69	35.43	50.25
Waste silage and meal	51.38	17.27	0.88	2.01	1.76	0.62	9.93	3.84	.25	3.78	5.90
Total consumed	416.62	144.38	6.80	21.26	20.11	6.54	79.44	30.31	3.44	31.65	44.35
" solid excrement	156.65	55.06	5.83	7.48	7.48	1.03	25.86	12.86	......	9.31	16.55
" digested	......	91.32	.97	13.78	12.63	5.51	53.58	17.45	3.44	22.34	27.80
Per cent. digested	......	63.25	14.26	64.82	62.80	84.25	67.45	57.57	100.00	70.58	62.70
Average of both goats	......	63.19	14.67	63.22	61.10	85.00	67.89	56.18	100.00	70.60	63.42

Mean nutritive ratio of ration of 1 pound of cotton-seed meal to 12 pounds corn silage. or on dry matter basis, 1 pound cotton-seed meal to 3.87 pounds corn silage, 1: 6.29.

In addition to determining the digestibility of this and the rations which follow, it was also the purpose of the experiments to study the effect of cotton-seed meal upon the digestibility of coarse fodders. The above ration, it will be observed, is materially more digestible than the silage alone, but less so than the mean of Armsby's and Wolff's coefficients show for the meal. Armsby's coefficients for cotton-seed meal were obtained upon sheep by feeding the meal with clover hay. What effect the meal exerted upon the digestibility of the hay, or *vice versa*, is unascertained. It is interesting to know, from both scientific and economic points of view, whether the digestibility of the ration here considered is merely a mean of the digestibility of silage when fed alone and of cotton-seed meal as determined by Armsby and Wolff, or whether one or both have influenced the digestibility of the other in the ration. In the tables which follow it has been attempted to bring out this point by calculating what would have been digested from the silage had it been fed alone by using our coefficients for it as thus fed, and what was digested from the meal by using the coefficients referred to above and subtracting these sums from what was actually digested in the ration. One obstacle to the above calculations was the wastes, which were part silage and part meal. Separation of these was quite impossible, but to err on the side of diminishing rather than enlarging the increased digestibility of the ration over the calculated results, the wastes were assumed to be only as digestible as silage alone, whereas their compositions, as shown in Table XV, indicate they were more digestible.

The results of these Tables (XVII and XVIII) arequ ite uniform in indicating the combination of silage and meal to be, on the whole, slightly more digestible than silage alone, and meal, as based upon the coefficients referred to. Like results to these in the next experiment are still more prominent.

TABLE XVII. SHOWING EFFECT OF COTTON-SEED MEAL UPON THE DIGESTIBILITY OF CORN SILAGE IN A RATION OF 12 LBS. SILAGE TO 1 LB. COTTON-SEED MEAL.

BLACK GOAT.

	Total Dry Matter	DRY MATTER CONTAINS IN OUNCES				
		Total Protein. N×6.25.	Albuminoids. N×6.25.	Fats. (Ether Extr'ct)	F-Free Extract.	Crude Fiber.
Amount digested from silage fed, calculated by using coefficients found for corn silage in Experiment 5	68.29	3.32	2.28	2.09	47.33	13.87
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's determinations of digestibility*	25.85	11.81	11.47	3.74	8.53	......
Total amount digested from ration, calculated by above coefficients	94.14	15.13	13.75	5.83	55.86	13.87
Less amount in waste, calculated by using same coefficients as for corn silage	10.58	.74	.50	.37	6.19	2.58
Calculated amount digested from silage and meal, as above	83 56	14.39	13.25	5.46	49.67	11.29
Actually digested from ration	89.50	13.02	11.87	5.66	54.09	15.72
Increased (+) or diminished (—) actual digestion over calculated	+5 94	—1.37	—1.38	+0 20	+4.42	+ 4.43
Per cent. of increase or diminution on basis of total consumed	+4.19	—6.48	—6.91	+3.03	+5.59	+15.73

GRAY GOAT.

	Total Dry Matter	Total Protein. N×6.25.	Albuminoids. N×6.25.	Fats. (Ether Extr'ct)	F-Free Extract.	Crude Fiber.
Amount digested from silage fed, calculated by using coefficients found for corn silage in Experiment 5	68.29	3.32	2.28	2.09	47.33	13 87
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's coefficients	25.85	11.81	11.47	3.74	8.53	......
Total amount digested from ration, calculated by above coefficients	94.14	15.13	13.75	5.83	55.86	13,87
Less amount in waste, calculated by using same coefficients as for corn silage	9.18	.69	.45	.41	6.01	1.66
Calculated amount digested from silage and meal, as above	84 96	14.44	13.30	5.42	49.85	12.21
Actually digested from ration	91.32	13.78	12.63	5.51	53.58	17.45
Increased (+) or diminished (—) actual digestion over calculated	+6.36	—0.66	—0.67	+0.09	+3 73	+ 5.24
Per cent. of increase or diminution on basis of total consumed	+4.40	—3.10	—3.33	+1.37	+4.69	+17.29

* Bulletin No. 3, Wis. Expt. Station: Dry matter 77.8, protein 86.7, fat 93.8, N-free extract 76.3, fiber 0.00.

9. DIGESTION OF RATION OF CORN SILAGE AND COTTON-SEED MEAL

BY STEERS NOS. 1 AND 2.

Date of Experiment, February, 1892.

Daily ration fed, 8 pounds corn silage to 1 pound cotton-seed meal
Steer No. 1, 44 " " 5½ " " "
" 2, 43 " " 5⅜ " " "
Total period, 17 days.
Feces collected, last 6 days.

Samples were taken for analysis of foods as given for the preceding experiment.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables XVIII and XIX.

TABLE XVIII. SHOWING PERCENTAGE COMPOSITION OF CORN SILAGE, COTTON SEED MEAL, WASTE, AND SOLID EXCREMENT.

	Moisture.	Dry Matter.	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Cotton-seed meal	8.35	91.65	7.28	42.96	41.32	11.32	31.93	6.51	.65	8.64
Corn silage	73.01	26.99	4.19	7.58	5.82	2.49	63.85	21.89	3.06	25.63
Waste cotton-seed meal and silage—Steer No. 2	64.82	35.18	7.16	26.15	23 20	6.72	42.81	17.16	1.67	16.07
Solid excrement—Steer No. 1	83.27	16.73	10 80	18 07	18.07	3.69	46 32	21.12	....	18 38
" " —Steer No. 2	82.75	17.25	10.82	16.72	16.72	3.05	44.94	24.47	....	16.68

TABLE XIX. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

STEER No. 1.

	Total Amo'nt.	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Cotton-seed meal fed	528.	483.91	35.23	207.89	199.95	54.78	154.51	31.50	3.14	41.81	109.56
Corn silage fed	4224.	1140.06	47.77	86.42	66.35	28.39	727.93	249.56	34.88	292.19	400.86
Total consumed	4752.	1623.97	83.00	294.31	266.30	83.17	882.44	281.06	38.02	334 00	510.42
" solid excrement	2996.5	501.31	54.14	90.59	90.59	18.50	232.21	105.88	......	92.14	140.07
" digested	......	1122.66	28.86	203.72	175.71	64.67	650.23	175.18	38.02	241.86	370.35
Per cent. digested	......	69.13	34.77	69.22	65.98	77.76	73.69	62.33	100.00	72.41	72.55

TABLE XIX—CONTINUED.

STEER No. 2.

	Total Amo'nt.	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Cotton-seed meal fed	516.	472.91	34 43	203.16	195.41	53.53	151.00	30.79	3 07	40 86	107.07
Corn silage fed	4128.	1114.15	46.68	84.45	64.84	27.74	711.38	243.89	34.09	285.55	391.74
Total fed	4644.	1587.06	81.11	287.61	260.25	81.27	862.38	274.68	37.16	326.41	498.81
Waste corn silage and cotton-seed meal	512.	180.12	12.90	47.10	41.79	12.10	77.11	30.91	3 00	28.94	45.17
Total consumed	4132.	1406 94	68.21	240.51	218 46	69.17	785.27	243.77	34.16	297.47	453 64
" solid excrement	2294.5	395.80	42.83	66.18	66 18	12.07	177.87	96.85	--- --	66.02	111.85
" digested	------	1011.14	25.38	174.33	152.28	57.10	607.40	146.92	34.16	231.45	341.79
Per cent. digested	------	71.87	37.21	72.48	69.71	82.55	77.35	60.27	100.00	77.80	75.34
Average per cent. digested	------	70.5	35.99	70.85	67.85	80.16	75.52	61.30	100.00	75.10	73.99

Mean nutritive ratio of ration of 1 pound cotton-seed meal to 8 pounds corn silage, or on dry matter basis, 1 pound of cotton-seed meal to 2.36 pounds corn silage, 1: 4.98

In the preceding experiment a ration of 12. pounds corn silage to 1 pound cotton-seed meal, having a nutritive ratio of 1 to 6.29, was fed. The ration in this experiment was 8 pounds corn silage to 1 pound cotton-seed meal, having a nutritive ratio of 1 to 4.98. The coefficients of digestibility of the latter ration, as would be expected, are much higher than those of the former, and the results presented in the tables below. like those for the former ration, are still more marked and interesting.

TABLE XX. SHOWING THE EFFECT OF COTTON-SEED MEAL UPON THE DIGESTIBILITY OF CORN SILAGE IN A RATION OF 8 LBS. CORN SILAGE TO 1 LB. OF COTTON-SEED MEAL.

STEER No. 1.

	Total Dry Matter Ozs.	DRY MATTER CONTAINS IN OUNCES					
		Ash.	Total Protein. (Nx6.25.)	Albuminoids. (Nx6.25.)	Fats. (Ether Ext.)	N-Free Ext.	Crude Fiber.
Amount digested from corn silage fed, calculated by using coefficients found for same	606.17	12.84	29.73	17.50	18.75	440.61	107.73
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's coefficients	376.48	------	180.24	173.36	51.38	117.89	------
Total digested from ration, calculated by above coefficients	982.65	------	209.97	190.86	70.13	558.50	107.73
Actually digested from ration	1122.66	------	203.72	175.71	64.67	650.23	175.18
Increased (+) or diminished (—) actual digestion over calculated	+140.01	------	—6.25	—15.15	—5.46	+91.73	+67.45
Per cent. of increase or diminution, on basis of total consumed	+ 8.62	------	—2.12	— 5.69	—6.56	+10.39	+23.99
Total digested from ration	1122.66	28.86	203.72	175.71	64.67	650.23	175.18
" " corn silage	606.17	12.84	29.73	17.50	18.75	440.61	107.73
Digested from cotton-seed meal, + increase due to the combination	516.49	16.02	173.99	158.21	45.92	209.62	67.45
Cotton-seed meal fed	483.91	35.23	207.89	199.95	54.78	154.51	31.50
Per cent. of digestibility of meal, and increase on basis of total meal fed	106.73	45.47	83.69	79.12	83.82	135.66	214.12

STEER No. 2.

	Total Dry Matter Ozs.	DRY MATTER CONTAINS IN OUNCES				
		Total Protein. (Nx6.25.)	Albuminoids. (Nx6.25.)	Fats. (Ether Ext.)	N-Free Ext.	Crude Fiber.
Amount digested from silage fed, calculated by using coefficients found for corn silage in Experiment 5	592.39	29.06	17.11	18.32	430.60	105.29
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's determination of digestibility	367.92	176.14	169.42	50.21	115.21	------
Total amount digested from ration, calculated by above coefficients	960.31	205.20	186.53	68.53	545.81	105.29
Less am't in waste, calculated by using same coefficients as determined in this ration	129.45	34.14	29.13	9.99	59.64	18.63
Calculated amount digested from silage and meal, as above	830.86	171.06	157.40	58.54	486.17	86.66
Actually digested from ration	1011.14	174.33	152.28	57.10	607.40	146.92
Increased (+) or diminished (—) actual digestion over calculated	+180,28	+3.27	—5.12	—1.44	+121.23	+60.26
Per ct. of increase or diminution, calculated on basis of total consumed	+ 12.81	+1.36	—2.35	—2.08	+ 15.44	+24.72

Steer No. 1 left no waste, and that of Steer No. 2 was assumed to be as digestible as what he ate, but its composition, as shown in Table XVIII, indicates that it was even more digestible. What he ate had the following percentage composition, calculated from the line of total consumed: Total protein, 17.1; fats, 4.9; nitrogen-free extract, 55.8; crude fiber, 17.3. A comparison of these figures with the composition of waste shows the waste contained more cotton-seed meal than what was eaten, and indicates very clearly that the waste was at least not less digestible than the portion eaten, thus throwing the error of the assumption on the side of decreasing the difference between the actual and calculated results.

The results in these tables show the total dry matter of the combination of silage and meal to be more digestible than silage alone and meal, calculated as in tables for first ration. The increase in this ration is double with one animal and triple with one what it was in the first. This growing increase in the digestibility of rations of silage and meal with the increase of the proportion of meal in the ration, and out of proportion to the digestibility of silage alone and of meal in the ration of meal and clover hay referred to, indicates that the highly nitrogenous cotton-seed meal has very favorably affected the digestibility of the corn silage. In experiments made heretofore upon the subject of determining the effect of protein substances and nitrogenous by-fodders upon the digestibility of coarse ones, and *vice versa*, the conclusion generally given out has been that neither influenced the digestibility of the other.*

As further evidence of the increased digestibility of the silage due to the cotton-seed meal in the ration, it will be observed from table for Steer No. 1, where there was no waste to be taken into account, that had it been attempted to calculate the digestibility of the meal in the ration in the way it is usually done, the digestibility of the silage being known, more than 100 per cent. would have been found digestible. Like data to this could not be shown in the other tables, on account of the wastes. It is, of course, manifestly impossible for the silage to thus affect the digestibility of the meal, and it remains but to say that the increased digestibility of the combinations is due, largely, at least, to the narrowing of the nutritive ratio of the corn silage by the highly nitrogenous cotton-seed meal, thereby accelerating, very materially, the amounts of digestible nitrogen-free extract and crude fiber of the silage, and decreasing slightly the amount of digestible protein, most likely of the cotton-seed meal. The nutritive ratio of the cotton-seed meal was widened by the presence of the corn silage, and the digestibility of its protein was probably decreased because of this, but this slight decrease does not, by any means, counterbalance the increase in the digestibility of the carbohydrates. The gain in carbohydrates is as much above the loss in protein as the increase in the actual digestion of the combination is above the calculated results. This is quite a perceptible and important increase. Besides, in our narrow ratio ration the slight loss of protein has passed into the manure pile as available nitrogen, whereas there is no such advantage accompanying the loss of carbohydrates in our wide ratio ration of corn silage, since the air furnishes inexhaustible supplies of the elements of carbohydrates, and they have no manurial value, except as humus. Then, too, it will be remembered that the heat and force-producing power of carbohydrates and protein in the animal body is only slightly different.

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* Armsby's Manual Cattle-feeding, page 277.

The foregoing discussion will be continued in the rations of cotton-seed hulls and cotton-seed meal later on.

10. DIGESTION OF COTTON-SEED HULLS

BY BRINDLE COW, BELLE OF BROOKSIDE,* AND BLACK, AND GRAY GOATS.

Date of Experiment—With Brindle Heifer, December and January, 1891–2.
" " —With Belle of Brookside, December, 1890.
" " —With Goats, January, 1892.

Ration fed—Brindle Cow, 9 pounds per day.
" —Belle of Brookside, 21 pounds per day.
" —Goats, each, 48 ounces.

Total period—Brindle Cow, 20 days.
" —Belle of Brookside, 12 days.
" —Goats, 16 days.

Collections made on last 6 days for all but Belle of Brookside, 4 days for her.

Samples for analysis were taken by placing an ounce of hulls in an air-tight jar at each feed.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables XXI, XXII, XXIII, XXIV, and XXV.

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*Previously reported in Bulletin 80c, Technical Bulletin No. 3.

TABLE XXI. SHOWING PERCENTAGE COMPOSITION OF COTTON-SEED HULLS, WASTE, AND SOLID EXCREMENT.

	Water. Per Cent	Dry Matter. Per Cent	DRY MATTER CONTAINS						
			Ash.	Albuminoids. (N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Cotton-seed hulls fed, Brindle Cow	16.73	83.27	2.13	4.42	3.42	44 58	45.45	.81	20.38
Waste, cotton-seed hulls, " "	18.52	81.48	2 27	4.39	3.24	44.52	45.58	.31	19.57
Solid excrement, " "	66.66	33.34	2.93	8.88	0.68	44.04	43.47	---	18.38

TABLE XXII. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

BRINDLE COW.

	Total Am't.	Dry Matter	DRY MATTER CONTAINS							
			Ash.	Albuminoids. (Alb. N×6 25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Cotton-seed hulls fed	720.	599.54	12.77	26 50	20.50	267.27	272 49	4.86	122.19	140.22
" " , waste	258.5	210.63	4 78	9.25	6 82	93.77	96.01	.65	41.22	51.90
Total consumed	......	388.91	7.99	17.25	13.68	173 50	176.48	4.21	80.97	88.32
" solid excrement	642.	214.00	6 27	19.00	1.46	94.24	93.03	... ..	40.29	53.95
" digested	......	174.91	1.72	—1.75	12.22	79.26	83.45	4.21	40 68	34.37
Per cent. digested	......	44.97	21.52	......	89.33	45.68	47.28	100.00	50.24	38.91

TABLE XXIII. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

BELLE OF BROOKSIDE.

	Total Dry Matter.	DRY MATTER CONTAINS							
		Ash.	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Fed in cotton-seed hulls	738.80	24.32	38.08	45.64	307.89	322.90	3.69	166.23	137.97
Total solid excrement	473.44	17.72	28 71	8.85	183.81	234 35	..	99 52	84.29
" digested	265.36	6.60	9.37	36.79	124 08	88.55	3.69	66.71	53 68
Per cent. digested	35 92	27.14	24.61	80.61	40.30	27.42	100.00	40.13	38.91

Nutritive ratio of cotton-seed hulls, Belle of Brookside, 1: 32.5.

TABLE XXIV. SHOWING PERCENTAGE COMPOSITION OF COTTON-SEED HULLS, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter.	DRY MATTER CONTAINS						
			Ash.	Protein. (N×6.25)	Fats. (Eth.Ext.)	N-Free Extr'ct.	Crude Fiber.	Total Sugars.	Starch.
Cotton-seed hulls fed	15.63	84.37	2.65	5.17	3.89	43.16	45.13	.74	20.77
Waste, cotton-seed hulls—Gray Goat	15.43	84.57	2.39	5.00	4.06	44.96	43.59	.68	20.38
" " —Black Goat	14.65	85.35	2.93	4.91	4.16	44.05	43.95	.68	20.22
Solid excrement—Gray Goat	51.49	48.51	3.94	9.30	0.63	45.58	40.55	---	19.12
" —Black Goat	46.84	53.16	3.08	9.59	1.00	46.30	40.03	---	18.81

TABLE XXV. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

GRAY GOAT.

	Total. Amount	Dry Matter.	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Fats. (Eth. Ext.	N-Free Extract.	Crude Fiber.	Total Sugars	Starch.	Undetermined Carbohydrates
Cotton-seed hulls fed	232	195.74	5.19	10.12	7.61	84.48	88.34	1.45	40.66	42.37
" " , waste	152.88	129.29	3.09	6.46	5.25	58.13	56.36	.88	26.35	30.90
Total consumed	------	66.45	2.10	3.66	2.36	26.35	31.98	.57	14.31	11.47
Solid excrement	85.78	41.61	1.64	3.87	0.26	18.97	16.87	------	7.96	11.01
Total digested	------	24.84	.46	—0.21	2.10	7.38	15.11	.57	6.35	.46
Per cent. digested	------	37.38	21.90	----------	88.98	28.01	47.25	100.00	44.37	4.01

BLACK GOAT.

	Total. Amount	Dry Matter.	Ash.	Protein. (N×6.25.)	Fats. (Eth. Ext.	N-Free Extract.	Crude Fiber.	Total Sugars	Starch.	Undetermined Carbohydrates
Cotton-seed hulls fed	200.00	168.74	4.47	8.72	6.56	72.83	76.15	1.25	35.04	36.54
" " waste	138.87	118.52	3.47	5.81	4.93	52.21	52.09	.81	23.96	27.44
Total consumed	161.13	50.22	1.00	2.91	1.63	20.62	24.06	.44	11.08	9.10
Solid excrement	55.71	29.62	.91	2.84	.30	13.71	11.86	------	5.57	8.14
Total digested	------	20.60	.09	.07	1.33	6.91	12.20	.44	5.51	.96
Per cent. digested	------	41.02	9.00	2.4	81.59	33.51	50.70	100.00	49.73	10.55
Average per cent. digested	------	39.20	15.45	1.2	85.28	30.76	48.97	100.00	47.05	7.28
Average of all 4 experiments	------	39.82	19.89	6.75	85.13	36.88	43.14	100.00	46.11	23.09

Nutritive ratio of cotton-seed hulls, average of four experiments, 1: 106.6.

Digestions of cotton-seed hulls have been made with four animals, two cows and two goats. The total protein digested by the Goats and Brindle Cow is much below that digested by Belle of Brookside, the amount excreted in dung by Gray Goat and Brindle Cow being more than what was consumed. This is most likely due to bile compounds, mucus, and other intestinal products not belonging to the undigested food residue proper. Extraction of the feces with ether, alcohol, hot water, and cold lime water* failed to lower the nitrogen in them. The coefficients for dry matter and nutrients other than protein make a first-rate showing for cotton-seed hulls. A low protein coefficient would be expected in a coarse fodder having so wide a nutritive ratio.

11. DIGESTION OF RATION OF COTTON-SEED HULLS AND COTTON-SEED MEAL

By Belle of Brookside† (1 lb. of Meal to 7 lbs. of Hulls).

Date of Experiment, December and January, 1890–'1.

Ration fed, 3 pounds of cotton-seed meal and 21 pounds of hulls per day.

Total period, 13 days.

Feces collected, last 4 days.

Samples for analysis were taken from each feed and enclosed in air-tight jars till end of experiment, then ground and mixed.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Table XXVI.

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* Jordan's Method. See Maine State Expt. Sta. Report, 1888, pp. 198–203.

† Technical Bulletin No. 3.

TABLE XXVI. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

	Total Dry Matter.	DRY MATTER CONTAINS							
		Ash.	Albuminoids. (N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Fed in cotton-seed hulls	1190.24	39.40	58.80	72 72	477.40	541.92	5.95	267.80	203.65
Fed in cotton-seed meal	178.69	13 15	76.91	19 55	53.86	15.22	1.30	14.47	38.09
Total consumed	1368.93	52.55	135.71	92 27	531.26	557.14	7.25	282.27	241.74
Solid excrement	754.60	34.58	75.59	17.72	258 28	368.44	......	137.79	120.49
Total digested	614 33	17.97	60.12	74 55	272.98	188.70	7.25	144.48	121.25
Per cent. digested	44.9	34.2	44.3	81.	51.4	33.9	100.00	51.19	50.16

Nutritive ratio of ration of 1 pound cotton-seed meal to 7 pounds cotton-seed hulls, 1: 10.8.

The above table is taken from Technical Bulletin No. 3, with the exception of the columns for sugars, starch, and undetermined carbohydrates, which have been added. The ration of 1 pound of cotton-seed meal to 7 pounds of hulls was fed to Belle of Brookside immediately after completing the experiment on the digestion of cotton-seed hulls with her, and is inserted here as being of interest in connection with the series of rations of cotton-seed meal and hulls.

In the following table (XXVII) are presented the same data for this ration that the preceding ones contain for the rations of meal and silage.

TABLE XXVII. SHOWING THE EFFECT OF COTTON-SEED MEAL UPON THE DIGESTIBILITY OF COTTON-SEED HULLS IN A RATION OF 1 LB. OF MEAL TO 7 LBS. OF HULLS.

BELLE OF BROOKSIDE.

	Total Dry Matter Ozs.	DRY MATTER CONTAINS IN OUNCES					
		Ash.	Total Protein. (Nx6.25.)	Albuminoids. (Nx6.25.)	Fats. (Ether Ext.)	N-Free Ext.	Crude Fiber.
Amount digested from cotton-seed hulls fed, calculated by using coefficients found in experiment with Belle of Brookside	427.30	10.69	15.93	15.93	58.61	192.39	146.86
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's coefficients	139.02	------	66.68	66.68	18.34	41.09	00.00
Total digested from ration, calculated by using above coefficients	566.32	------	82.61	82.61	76.95	233.48	146.86
Actually digested from ration	614.33	17.97	60.12	60.12	74.55	272.98	188.70
Increased (+) or diminished (—) actual digestion over calculated	+48.01	------	—22.49	—22.49	—2.40	+ 39.50	+ 41.84
Per cent. of increase or diminution, on basis of total consumed	+ 3.51	------	—16.57	—16.57	—2.60	+ 7.43	+ 7.51
Total digested from ration	614.33	17.97	60.12	60.12	74.55	272.98	188.70
Digested from cotton-seed hulls alone	427.30	10.69	15.93	15.93	58.61	192.39	146.86
Digested from cotton-seed meal, + increase due to the combination	187.03	7.28	44.19	44.19	15.94	80.59	41.84
Cotton-seed meal fed	178.69	13.15	76.91	76.91	19.55	53.86	15.22
Per cent. of digestibility of meal, and increase on basis of total meal fed	104.67	55.36	57.45	57.45	81.53	149.63	274.90

The cotton-seed hulls were given the same coefficients of digestibility in this ration as were found in the experiment with this animal, as they were thought to be more nearly correct for her, while in the remaining rations the mean coefficients of the four experiments have been used.

The results here, in harmony with those in the rations of silage and meal, show the combination to be, on the whole, slightly more digestible than hulls alone and meal in the rations from which its coefficients were obtained. The nutritive ratio of this ration is quite wide (1 to 10.8), and the decrease in digestible protein considerable, but this is more than compensated for in the increase of digestible carbohydrates.

The digestibility of the dry matter of cotton-seed meal as obtained from this ration is above 100, the protein and the fat less digestible than Armsby's and Wolff's determinations show, while one-and-a-half and two-and-three-fourths times as much nitrogen-free extract and crude fiber respectively are digested as the meal contained. These excesses, of course, come from the increased digestibility of the cotton-seed hulls.

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12. DIGESTION OF RATION OF COTTON-SEED HULLS AND MEAL

BY STEERS, YELLOW AND LINEBACK. (1 LB. OF MEAL TO 6 LBS. OF HULLS.)

Date of Experiment, December and January, 1891–2.

Ration fed—Yellow Steer, 21 lbs. hulls, 3½ pounds meal per day.
" —Lineback, 24 " 4 " " "

Total period, 20 days.

Feces collected, last 5 days.

Samples for analysis were taken by putting a small aliquot part of each feed into an air-tight jar.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables XXVIII and XXIX.

TABLE XXVIII. SHOWING PERCENTAGE COMPOSITION OF COTTON-SEED HULLS AND MEAL, WASTE, AND SOLID EXCREMENT.

	Water.	Dry Matter.	DRY MATTER CONTAINS							
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Cotton-seed hulls fed	16.73	83.27	2.13	4.42	4.42	3.42	44.58	45.45	.81	20.46
Cotton-seed meal fed	7.97	92.03	7.05	41.08	40.20	10.53	34.76	6.58	.80	8.02
Hulls and meal, waste—Yellow	24.85	75.15	2.76	6.65	6.65	3 66	41.50	45.43	.41	19.35
" " " —Lineback	15.52	84.48	2.75	6 68	6.68	3.71	42.45	44.41	.37	20 27
Solid excement—Yellow	75.15	24.85	4.22	10.95	10.95	1.95	40 31	42.57	---	18.35
" " —Lineback	76.35	23.65	3.84	9.98	9.98	1.06	40 62	44 50	---	18.22

TABLE XXIX. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

YELLOW STEER.

	Total Amo'nt.	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Cotton-seed hulls fed	1680.	1398 9	29.80	61.83	61 83	47.84	623.63	635.80	11.33	286.21	326.09
Cotton.seed meal fed	280.	257.7	18.17	105.86	103.60	27.14	89.57	16.96	2.06	20.67	66.84
Total fed	1960.	1656.6	47.97	167.69	165.43	74.98	713.20	652.76	13.39	306.88	392.93
Cotton-seed hulls and meal, waste	141 6	106.4	2.94	7.08	7.08	3.89	44.16	48.31	.44	20.59	23.13
Total consumed	1818.4	1550.2	45.03	160.61	158.35	71.09	669.04	604.42	12.95	286.29	369.80
" solid excrement	3516.	873.7	36 87	95.67	95.67	17.04	352 19	371.93	------	160.32	191.87
" digested	------	676 5	8.16	64 94	62.68	54.05	316.85	232.49	12.95	125.97	177.93
Per cent. digested	------	43.64	18.12	40.43	39.58	76.03	47.36	38.46	100.00	44.00	48.11

TABLE XXIX.—CONTINUED.

LINEBACK.

	Total Amount	Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.	Undetermined Carbohydrates
Cotton-seed hulls fed	1920.	1598.8	34.05	70.67	70.67	54.68	712.74	726.65	12.95	327.12	372.67
Cotton-seed meal fed	320.	294.5	20.76	120.98	118.39	31.01	102.37	19.38	2.36	23.62	76.39
Total fed	2240.	1893.3	54.81	191.65	189.06	85.69	815.11	746.03	15.31	350.74	449.06
Cotton-seed hulls and meal, waste	178.75	151.0	4.15	10.09	10.09	5.60	64.10	67.06	.56	30.61	32.93
Total consumed	2061.25	1742.3	50.66	181.56	178.97	80.09	751.01	678.97	14.75	320.13	416.13
" solid excrement	3751.0	887.1	34.06	88.53	88.53	9.40	360.34	394.76	......	161.63	198.71
" digested	....	855.2	16.60	93.03	90.44	70.69	390.67	284.21	14.75	158.50	217.42
Per cent. digested by Lineback	....	49.09	32.77	51.24	50.53	88.26	52.02	41.86	100.00	49.51	52.25
Average of both steers	....	46.36	25.44	45.83	45.05	82.14	49.69	40.16	100.00	46.75	50.18

Mean nutritive ratio of ration of 1 pound of cotton seed meal to 6 pounds of cotton seed hulls, 1: 9.71.

There is very little increase, taking an average of the two steers, in the digestibility of this ration of 1 pound of cotton-seed meal to 6 pounds cotton-seed hulls over the 1 to 7 just preceding. In fact, the difference in composition of what was eaten of the two is slight, the nutritive ratio being 1 to 9.71 in the latter against 1 to 10.8 in the former ration.

The data for the 1 to 6 ration, like that for the preceding ones, follow in the table (XXX).

TABLE XXX. SHOWING THE EFFECT OF COTTON-SEED MEAL UPON THE DIGESTIBILITY OF COTTON-SEED HULLS IN A RATION OF 1 POUND OF MEAL TO 6 POUNDS OF HULLS.

	DRY MATTER CONTAINS IN OUNCES					
	Total Dry Matter Ozs.	Total Protein. (N×6.25)	Albuminoids. (Alb. N×6.25)	Fats. (Ether Extr'ct)	N-Free Extract.	Crude Fiber.
YELLOW STEER.						
Amount digested from cotton-seed hulls fed, calculated by using mean coefficients for the same	556.76	4.17	4.17	40.71	229.99	274.41
Amount digested from cotton-seed meal, calculated by using mean of Armsby's and Wolff's coefficients	200.49	91.78	89.82	25.46	68.34	0.00
Total amount digested from hulls and meal, calculated by using above coefficients	757.25	95.95	93.99	66.17	298.33	274.41
Less amount in waste, calculated by using same coefficients as for cotton-seed hulls	42.35	.48	.48	3.31	16.28	20.86
Total digested from ration, calculated by using above coefficients	714.90	95.47	93.51	62.86	282.05	253.55
Actually digested from ration	676.50	64.94	62.68	54.05	316.85	232.49
Increased (+) or diminished (—) actual digestion over calculated	—38.40	—30.53	—30.83	— 8.81	+34.80	—21.06
Per ct. of increase or diminution on basis of total consumed	— 2.47	—19.00	—19.47	—12.39	+ 5.20	— 3.48
LINEBACK STEER.						
Amount digested from cotton-seed hulls fed, calculated by using mean coefficients found for the same	636.32	4.77	4.77	46.53	262.86	313.62
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's coefficients	229.12	104.89	102.64	29.09	78.11	0.00
Total digested from hulls and meal, calculated by using above coefficients	865.44	109.66	107.41	75.62	340.97	313.62
Less amount in waste, calculated by using same coefficients as for cotton-seed hulls	60.10	0.68	0.68	4.77	23.64	28.94
Total digested from ration, calculated by using above coefficients	805.34	108.98	106.73	70.85	317.33	284.68
Actually digested from ration	855.20	93.03	90.44	70.69	390.67	284.21
Increased (+) or diminished (—) actual digestion over calculated	+49.86	—15.95	—16.29	+0.16	+73.34	—00.47
Per ct. of increase or diminution on basis of total consumed	+ 2.86	— 8.78	— 9.10	+0.20	+ 9.77	—00.07

The wastes of both steers were assumed to be only as digestible as cotton-seed hulls, whereas their compositions show they were more digestible, thus throwing the error of the assumption, as in former experiments, on the side of diminishing the difference between the actual and calculated results.

The digestibility of the combination of hulls and meal by *Yellow Steer* is below the calculated results for hulls and meal, and is the only exception in the entire series of digestions to the general rule of increased digestibility of the rations of hulls and meal over the results for hulls alone and meal as calculated. It would appear, by reference to the coefficients for Yellow Steer for this ration, in Table XXIX, that he was not up to his full digestive capacity during this trial,* as the coefficients for dry matter and all the nutrients for him are materially below those for Lineback, the duplicate steer on this ration, and, because of this, the mean coefficients for the two steers for the ration are probably lower than they should be. In evidence of the off condition of the Yellow Steer on this ration it will be observed that he digested almost up to the Lineback Steer in the next ration, 1 pound of meal to 4 pounds of hulls. In view of the above facts it would appear that the decreased digestibility of the combination was due to the animal rather than to the ration.

The results for Lineback Steer show the combination of hulls and meal to be slightly more digestible than the calculated results for the same.

13. DIGESTION OF A RATION OF COTTON-SEED HULLS AND MEAL

By Steers, Lineback and Yellow. (1 lb. of Meal to 4 of Hulls.)

Date of Experiment, January and February, 1892.

Rations fed—Lineback, 20 lbs hulls and 5 lbs. meal per day.
" —Yellow Steer, 18 " " 4½ " "

Total period, 15 days.

Feces collected, last 6 days.

Samples for analysis were taken by putting an aliquot sample of food in an air-tight jar at each feed.

Analytical and Other Data for Obtaining the Coefficients of Digestibility. See Tables XXXI and XXXII.

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* Yellow was slightly scoured for a few days during this period.

TABLE XXXI. SHOWING PERCENTAGE COMPOSITION OF COTTON-SEED HULLS AND MEAL, WASTE, AND SOLID EXCREMENT.

	Water	Dry Matt'r	DRY MATTER CONTAINS							
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extract	Crude Fiber.	Total Sugars.	Starch.
Cotton-seed hulls fed	15.26	84.74	2.46	4.37	4 37	2.94	43.71	46.52	.65	20.09
Cotton-seed meal fed	7.71	92.29	7.19	41 04	39 82	12.00	33 67	6.10	.94	8.09
Waste, cot-seed hulls and meal—Lineback	16.84	83.16	2.97	6.51	6.51	4.12	41.16	45.24	.41	18.55
" " " " —Yellow	17 24	82.76	2.86	8.24	8.24	3.93	41.63	43.34	.31	18 73
Solid excrement—Lineback	77.00	23 00	3.89	12.13	12.13	1.33	38.11	44.54	---	15.98
" " —Yellow	77 69	22.31	4.27	12.48	12.84	1.89	37.22	44.14	---	16.50

TABLE XXXII. SHOWING NUTRIENTS CONSUMED AND EXCRETED IN OUNCES, WITH PERCENTAGES DIGESTED.

LINEBACK.

	Total Amo'nt.	Total Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25)	Fats. (Eth. Ext.)	N-Free Extr'ct	Crude Fiber.	Total Sugars.	Starch.	Undet'rmined Carb'hydrates
Cotton-seed hulls fed	1824.	1545.7	38.02	67.55	67 55	45 44	675.63	719 06	10.05	310.53	355.05
" " meal fed	456.	420.8	30 26	172.70	167 56	50.50	141.68	25 67	3.96	34.04	103.68
Total fed	2280.	1966 5	68.28	240.25	235.11	95.94	817.31	744.73	14.01	344.57	458.73
Waste, hulls and meal	126 38	105.1	3 12	6.84	6.84	4.33	43.26	47.55	.43	19.50	23 33
Total consumed	--------	1861.4	65 16	233.41	228.27	91.61	774.05	697.18	13.58	325 07	435.40
" solid excrement	3687.	848.0	32 99	102.86	102.86	11.28	323.17	377.70	------	135.51	187.66
" digested	--------	1013.4	32.17	130.55	125.41	80.33	450.88	319.48	13.58	189.56	247.74
Per cent. digested	--------	54.44	49.37	55.93	54.94	87.69	58.25	45.82	100.00	58.31	56.90

TABLE XXXII.—CONTINUED.

YELLOW STEER.

	Total Amount	Total Dry Matter.	DRY MATTER CONTAINS								
			Ash.	Total Protein. (N×6.25.)	Albuminoids. (Alb. N×6.25.)	Fats. (Eth. Ext.)	N-Free Extr'ct	Crude Fiber.	Total Sugars.	Starch.	Undet'rmined Carb'hydrates
Cotton-seed hulls fed	1728.	1464.3	36.02	63.99	63.99	43.05	640.04	681.19	9.52	294.18	336.34
" " meal fed	432.	398.7	28.67	163.63	158.76	47 84	134.24	24.32	3 75	32.25	98.24
Total fed	2160.	1863.0	64.69	227.62	222.75	90.89	774.28	705.51	13 27	326.43	434.58
Waste, hulls and meal	174.5	144.4	4.13	11.90	11.90	5.67	60.11	62.58	.45	27.05	32.61
Total consumed	......	1718.6	60.56	215.72	210.85	85.22	714 17	642.93	12.82	299.38	401.97
" solid excrement	3649.	814.1	34.76	101.60	101.60	15.39	303.01	359.34	......	134.33	168.68
" digested	......	904.5	25.80	114.12	109.25	69.83	411.16	283.59	12.82	165.05	233.29
Per cent. digested	......	52.63	42.60	52.90	51 81	81.94	57.57	44.11	100.00	55.13	58.03
Mean of both steers	......	53.53	45.98	54.41	53.37	84.81	57.91	44.96	100.00	56.72	57.40

Mean nutritive ratio of ration 1 pound of cotton-seed meal to 4 pounds of cotton-seed hulls, 1: 7.52, There has been a gradual increase in the digestibility of the rations of hulls and meal with the increased addition of meal. The digestibility of the dry matter of the 1 to 7 ration was 45 per cent., of the 1 to 6 ration 49 per cent.,* of the 1 to 4 ration 53.5 per cent. This increase here, as with the rations of silage and meal, is in excess of the average between the digestibility of hulls alone and of meal, as obtained from the rations referred to.

The results upon this point for the ration of 1 to 4 are contained in the table herewith (XXXIII).

TABLE XXXIII. SHOWING THE EFFECT OF COTTON-SEED MEAL UPON THE DIGESTIBILITY OF COTTON-SEED HULLS IN A RATION OF 1 LB. MEAL TO 4 LBS. HULLS.

LINEBACK STEER.

	Total Dry Matter Ozs.	DRY MATTER CONTAINS IN OUNCES				
		Total Protein. (Nx6.25.)	Albuminoids. (Alb. Nx6.25.)	Fats. (Ether Ext.)	N-Free Ext.	Crude Fiber.
Amount digested from cotton-seed hulls fed, calculated by using mean coefficients for same	615.19	4.56	4.56	38.67	249.17	310.35
Amount digested from cotton-seed meal, calculated by using mean of Armsby's and Wolff's coefficients	327.38	149.73	145.27	47.37	108.10	0.00
Total digested from hulls and meal, calculated by using above coefficients	942.57	154.29	149.83	86.04	357.27	310.35
Less am't in waste, calculated by using same coefficients as for cotton-seed hulls	41.83	.46	.46	3.68	15.95	20.52
Total digested from ration, calculated by using above coefficients	900.74	153.83	149.37	82.36	341.32	289.83
Actually digested from ration	1013.40	130.55	125.41	80.33	450.88	319.48
Increased (+) or diminished (–) actual digestion over calculated	+112.66	–23.28	–23.96	–2.03	+109.56	+29.65
Per cent. of increase or diminution, on basis of total consumed	+ 6.05	– 9.97	–10.49	–2.21	+ 14.15	+ 4.25

YELLOW STEER.

	Total Dry Matter Ozs.	Total Protein. (Nx6.25.)	Albuminoids. (Alb. Nx6.25.)	Fats. (Ether Ext.)	N-Free Ext.	Crude Fiber.
Amount digested from cotton-seed hulls fed, calculated by using mean coefficients for same	582.79	4.32	4.32	36.64	236.05	294.00
Amount digested from cotton-seed meal fed, calculated by using mean of Armsby's and Wolff's coefficients	310.19	141.87	137.64	44.87	102.42	0.00
Total digested from hulls and meal, calculated by using above coefficients	892.98	146.19	141.96	81.51	338.47	294.00
Less amt. in waste, calculated on basis of same coefficients as for cotton-seed hulls	57.47	.80	.80	4.83	22.17	27.00
Total digested from ration, calculated by using above coefficients	835.51	145.39	141.16	76.68	316.30	267.00
Actually digested from ration	904.50	114.12	109.25	69.83	411.16	283.59
Increased (+) or diminished (–) actual digestion over calculated	+68.99	–31.27	–31.91	–6.85	+94.86	+16.59
Per cent. of increase or diminution, on basis of total consumed	+ 4.01	–14.49	–15.13	–8.04	+13.28	+ 2.58

The nutritive ratio of the 1 to 4 ration of meal and hulls is one wider than the 1 to 12 ration of meal and silage. The increase in the digestibility of the 1 to 12 combination of meal and silage by both steers, and of the 1 to 4 combination of meal and hulls by Yellow Steer is practically the same, while the increase with Lineback Steer on the latter is one-third greater. The digestibility of the combination of silage and meal and cotton-seed hulls and meal have gradually increased over the calculated results for the same, with the narrowing of the nutritive ratio. It would seem, therefore, in the light of the foregoing experiments, that a still narrower ration of cotton-seed hulls and meal could often be advantageously fed for economic production of beef, milk, or work, as it is believed that a still larger amount of digestible nutrients would thus be obtained than are shown in the preceding rations of hulls and meal.

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* Not including Yellow Steer.

14. DIGESTIBLE ORGANIC NUTRIENTS

In 100 Pounds of Dry Matter of Fodders and Rations.

The data presented in Table XXXIV makes it easy to compare the digestible nutrients and value of the fodders and rations considered in this Bulletin.

TABLE XXXIV. Showing the Pounds of Digestible Organic Nutrients in One Hundred Pounds of Dry Matter of Each Food and Ration, with the Nutritive Ratios.

	Digestible Protein.	Digestible Non-Nitrogenous Nutrients.		Total Nutritive Organic Substance.	Nutritive Ratio.
		Fats.	Other Carbohydrates.		
Corn fodder	6.02	2.61	45.79	54.42	1: 8.73
Crimson clover hay	12.45	1.25	43.70	57.40	1: 3.76
Cowpea-vine hay	9.18	.75	46.52	56.45	1: 5.27
Soja bean silage	11.90	6.22	34.66	52.78	1: 4.22
Corn silage	2.59	1.63	47.64	51.86	1: 19.96
Cotton-seed hulls, av. of 4 experiments	.42	3.81	35.27	39.50	1: 106.6
Ration of 1 lb. cotton-seed meal to 7 lbs. cotton seed hulls	4.39	5.46	33.70	43.55	1: 10.78
Ration of 1 lb. cotton-seed meal to 6 lbs. cotton-seed hulls	4.76	3.77	36.88	45.41	1: 9.71
Ration of 1 lb. cotton-seed meal to 4 lbs. cotton-seed hulls	6.82	4.19	40.84	51.85	1: 7.52
Ration of 1 lb. cotton-seed meal to 3.87 lbs. corn silage	9.36	3.90	49.17	62.43	1: 6.29
Ration of 1 lb. cotton-seed meal to 2.36 lbs. corn silage	12.47	4.03	52.09	68.59	1: 4.98
Ration of 1 lb. raw cotton-seed to .88 lb. corn silage	7.53	11.67	39.46	58.66	1: 9.12
Ration of 1 lb. roasted cotton-seed to .60 lb. corn silage	5.41	9.82	39.14	54.37	1: 11.77
Raw cotton-seed	11.91	20.46	33.73	66.09	1: 7.13
Roasted cotton-seed	8.33	17.79	32.08	58.20	1: 9.19

15. ACTUAL VS. CALCULATED NUTRITIVE RATIOS OF RATIONS.

In the digestion of the preceding rations of cotton-seed meal and corn silage and cotton-seed meal and cotton-seed hulls, the protein actually digested is below (only slightly so on an average in the rations of meal and silage, but more markedly so in the wider ratio rations of meal and hulls) the amounts calculated for the single foods, whereas the nitrogen-free extract actually digested from the rations is in all cases much greater, and the crude fiber, as a general rule, is larger than the amounts calculated for the single foods. Both these factors of decreased digestibility of protein and increased digestibility of carbohydrates tend to widen the nutritive ratio, and make it apparent that the nutritive ratio of rations calculated from the coefficients of digestibility of their constituent foods may be, and are, in the rations under consideration, quite different from the ratios obtained by actual digestion of the rations.

In the table following are brought together the nutritive ratios of the rations determined by actual digestions of them and the nutritive ratios of the same rations calculated from the coefficients of digestibility of their constituent foods.

Animals.	Ration.	No. Determinations	Nutritive Ratio by Actual Digestion	Nutritive Ratio Calculated from Single Foods.
Goats	Cotton-seed meal and corn silage, 1 to 12	2	1: 6.29	1: 5.57
Steers	Cotton-seed meal and corn silage, 1 to 8	2	1: 4.98	1: 4.01
Heifer	Cotton-seed meal and cot.-seed hulls, 1 to 7	1	1: 10.8	1: 6.93
Steers	Cotton-seed meal and cot.-seed hulls, 1 to 6	2	1: 9.71	1: 7.69
Steers	Cotton-seed meal and cot.-seed hulls, 1 to 4	2	1: 7.52	1: 5.62

16. COMPARATIVE DIGESTIVE POWER

OF SHEEP AND GOATS, AND COWS AND GOATS FOR THE SAME FOODS.

Few or no digestion experiments with goats have been made in this country. Their digestive power for the various fodders, judging from European investigations, is practically the same as that of sheep and oxen. The digestions of corn fodder, crimson clover hay, and cowpea-vine hay by one goat and one sheep on each, furnish data for comparing the digestive powers of sheep and goats for these three fodders, while the digestions of cotton-seed hulls by two goats and two heifers furnish data for making like comparisons for goats and cows. Combining the coefficients for the sheep and cows for the four fodders, we have data for comparing the digestive powers of sheep and cows with goats for the four fodders. There is practically no difference in the amounts of dry matter digested by goats and sheep, and goats and cows from these fodders. Making comparison, however, of the goats and sheep on the individual nutrients, it will be seen that the goats digested more protein, practically the same amount of fats, and less nitrogen-free extract and fiber than the sheep. In comparison with the cows on cotton-seed hulls, the goats digested on an average less protein, practically an equal amount of fats, less nitrogen-free extract, and more fiber. The results are embodied in Table XXXV.

TABLE XXXV. COMPARISON OF THE DIGESTIVE POWERS OF GOATS AND SHEEP, AND GOATS AND COWS.

ANIMALS AND FOODS.	No. Determinations.	Dry Matter.	Ash.	Protein.	Albuminoids.	Fats. (Eth. Extract.)	N-Free Extract.	Fiber.	Sugar.	Starch.	Undetermined Carbohydrates.
Black Goat—Corn fodder	1	54.85	15.67	68.76	63.50	65.42	57.08	54.27	100.00	63.45	42.38
Gray Goat—Crimson clover hay	1	59.44	53.44	68.52	59.39	43.72	69.34	42.57	100.00	65.66	67.85
Black Goat—Cowpea-vine hay	1	59.28	53.89	65.14	48.52	53.71	70.61	41.24	100.00	61.88	71.05
Black and Gray Goats—Cotton-seed hulls	2	39.20	15.45	1.20	1.20	85.28	30.76	48.97	100.00	47.05	7.28
Mean for Goats for the four fodders		53.19	34.61	50.90	43.15	62.03	56.95	46.76	100.00	59.51	47.14
Mean for goats for corn fodder, crimson clover, and cowpea-vine hay		57.86	41.00	67.47	57.13	54.28	65.67	46.02	100.00	63.66	60.42
Horned Sheep—Corn fodder	1	56.22	11.29	43.15	41.56	60.59	60.65	67.04	100.00	69.98	42.59
Hornless Sheep—Crimson clover hay	1	65.00	53.65	69.75	61.06	53.96	73.63	54.82	100.00	70.67	72.07
Horned Sheep—Cowpea-vine hay	1	59.18	36.40	63.94	46.56	46.36	70.71	44.59	100.00	65.49	69.02
Belle of Brookside and Brindle—Cot.-seed hulls	2	40.44	24.33	12.30	12.30	84.96	42.99	37.35	100.00	45.18	38.91
Mean of Sheep and Cows for the four fodders		55.21	31.42	47.28	40.37	61.47	61.99	50.95	100.00	62.83	55.65
Mean of Goats for the four fodders		53.19	34.61	50.90	57.13	62.03	56.95	46.76	100.00	59.51	47.14
Mean of Sheep for corn fodder, crimson clover, and cowpea-vine hay		60.13	33.78	58.94	49.73	53.63	68.33	55.48	100.00	68.71	61.22
Mean of Goats for corn fodder, crimson clover, and cowpea-vine hay		57.86	41.00	67.47	57.13	54.28	65.67	46.02	100.00	63.66	60.42

17. THE NITROGEN-FREE EXTRACT OF FOODS.*

The term "nitrogen-free extract" as used in the ordinary fodder analysis represents sugars, starch, gums, mucilages, organic acids, etc., or the difference between 100 and the sum of protein, fiber, fats, and ash. In coarse fodders, very often, the nitrogen-free extract is half, or more, of the total constituents of the food, and is of too varied composition and nature to be thrown in so loosely. A step of progress has recently been made in the separation of the constituents of the nitrogen-free extract by the introduction of a method for the determination of the pentaglucoses. These varied bodies of the nitrogen-free extract are claimed to have, and perhaps do have, different coefficients of digestibility and nutritive value, but the data upon which to base an opinion of either is rather meager.

In the present experiments total sugars and starch have been determined, and all the nitrogen-free extract not represented in them is included under the head of "Undetermined Carbohydrates." Under the heading of "Total Sugars" is represented all the cold water extract substances capable of reducing Fehling's copper solution, and is really more than the true sugars, while under the heading of "Starch" is included all copper-reducing bodies obtained by treating the residue from the "total sugars" with 150^{cc} water and 4^{cc} hydrochloric acid in an Erlenmeyer flask, with a reflux condenser, on water-bath for 12 hours. This, too, of course, is not all starch, for other bodies than starch have no doubt been converted into sugars, but duplicate determinations gave fairly concordant results, showing pretty constant conversion power of the acid.

Though "total sugars" and "starch" do not here represent definite classes of bodies, they are of interest as a means of comparison with similar results. The New York State Experiment Station has made determinations of the digestibility of sugars and starch in some hays and rations, and concludes that "the total of sugars and starch digested in each ration falls a little short of the total amount of nitrogen-free extract digested."† The method used by this Station and the New York Station for sugars and starch was practically the same.

As will be seen from the table following, the sugars were in all cases completely digested. The coefficients of digestibility of the "undetermined carbohydrates" of corn fodder, soja bean silage, rations of raw and roasted cotton-seed and corn silage, raw and roasted cotton-seed, and cotton-seed hulls are much lower than the corresponding ones for starch for the same fodders and rations, but with the remaining fodders and rations there was very little difference in the digestibility of starch and "undetermined carbohydrates." (See Table XXXVI.)

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* Mr. J. S. Meng made the determinations of sugars and starch, and to him is due credit for the analytical work on this subject as presented in this Bulletin.

† Eighth Annual Report New York (Geneva) Experiment Station.

TABLE XXXVI. SHOWING THE COEFFICIENTS OF DIGESTIBILITY OF SUGARS, STARCH, AND UNDETERMINED CARBOHYDRATES IN FODDERS AND RATIONS.

FOODS.	No. Determinations.	Total Sugars.	Starch.	Undetermined Carbohydrates.
Corn fodder	2	100.00	66.71	42.48
Crimson clover hay	2	100.00	68.16	70.01
Cowpea-vine hay	2	100.00	63.68	70.03
Soja bean silage	2	100.00	68.41	0.21
Corn silage	1	100.00	55.16	61.43
Ration raw cotton-seed and corn silage	2	100.00	62.58	45.03
Raw cotton-seed	2	100.00	75.63	21.14
Roasted cotton-seed	2	100.00	77.91	8.48
Ration roasted cotton-seed and corn silage	2	100.00	63.97	41.43
Ration cotton-seed meal and corn silage, 1 to 12	2	100.00	70.60	63.42
" " " " " 1 to 8	2	100.00	75.10	73.99
Cotton-seed hulls	4	100.00	46.11	23.09
Ration cotton-seed meal and hulls, 1 to 7	1	100.00	51.19	50.16
" " " " " 1 to 6	2	100.00	46.75	50.18
" " " " " 1 to 4	2	100.00	56.72	57.46

18. SUMMARY OF COEFFICIENTS OF DIGESTIBILITY.

In order that the work concluded in these digestions may be more conveniently examined and compared, the coefficients of digestibility of the various fodders and rations are brought together in one table. (See Table XXXVII.)

TABLE XXXVII. SUMMARY OF COEFFICIENTS OF DIGESTIBILITY.

FOODS.	No. of Separate Determinati'ns	Dry Matter.	Ash.	Protein.	Albuminoids.	Fats (Eth. Ext).	N-Free Ext.	Crude Fiber.
Pulled fodder (corn leaves)	2	55.5	13.5	56.	52.5	63.	58.9	60.7
Crimson clover hay	2	62.2	53.6	69.1	60.2	48.8	71.5	48.7
Cowpea-vine hay	2	59.2	45.1	64.5	47.5	50.0	70.7	42.9
Soja bean silage	2	59.	56.7	75 8	66.1	71 9	52.0	54.8
Corn silage	1	53.2	26.9	34 4	26.4	66.0	60.5	43.2
Ration corn silage and raw cotton-seed, 2.66 lbs. to 1 lb., or on basis of dry matter, .88 to 1 lb	2	60.	34.9	58.6	55.4	85.4	55.4	59.9
Raw cotton-seed	2	66.1	43.3	67.9	63.6	87.1	49.6	75.5
Roasted cotton-seed	2	55.9	0.0	47.0	44.2	71.7	51.4	65.9
Ration 1 lb. roasted cotton-seed to 2 lbs. corn silage, or on basis of dry matter, 1 to .6 lbs	2	54.6	5.9	43.2	40 3	71.2	57.1	53.
Ration corn silage and cotton-seed meal, 12 to 1, or on basis of dry matter, 3.87 to 1 lb	2	63.2	14.7	63.2	61.1	85.0	67.9	56.2
Ration corn silage and cotton-seed meal, 8 to 1, or on basis of dry matter, 2.36 to 1 lb	2	70.5	36.0	70.9	67.9	80.2	75.5	61.3
Cotton-seed hulls	4	39.8	19.9	6.75	6.75	85.1	36.9	43.1
Ration cotton-seed hulls and meal, 7 to 1 lbs	1	44.9	34.2	44.3	44.3	81.	51.4	33.9
Ration cotton-seed hulls and meal, 6 to 1 lbs	2	46.4	25.4	45 8	45.1	82.1	49.7	40.2
Ration cotton-seed hulls and meal, 4 to 1 lbs	2	53.5	46.0	54.4	53.4	84.8	57.9	45.0

19. CONCLUSIONS.

The object of these experiments has been to determine and bring together data by which stock-breeders and feeders can easily fix on the kinds of cattle foods or by-products which are best to feed together for economical growth, work, or production of milk or meat.

The coefficients of digestibility thus far found will, of course, be subject to modifications when other determinations have been made, but the larger the number entering into the composition of a mean, or average, will bring that mean nearer the probable digestibility for fodders and rations of the several kinds as they are found throughout the country.

These coefficients, brought together in the preceding table from the previous pages, will be used in compiling handy tables for every-day use, with others from various sources. These, it is hoped, will soon be available for practical feeders.

The digestion of rations has been undertaken here with articles of wide ratios, and therefore show markedly the effect of narrowing the ratio. These results of digesting rations of increasing amounts of highly nitrogenous by-fodder in proportion to the coarse fodder, are of the greatest importance to stockmen. It illustrates how they can get the most possible out of coarse fodders, make their stock digest much larger quantities of those compounds, which, when thrown off in the manure pile, have no value except as humus in the soil, while they will help to maintain and fatten the stock. At the same time comparatively large quantities of nitrogen, potash, and phosphoric acid will be adding to the intrinsic value of their manure piles, and greater care will be needed to prevent waste there.

Digestion experiments have been made on at least forty of the most common and important American cattle foods, yet few rations have been subjected to digestion with a view to compare actual digestion with what is assumed where rations are compounded for stock. A beginning was made in New York* with hay as the coarse fodder, to which grain mixtures were added. That important subject has been continued in the work outlined in the present bulletin, and it is believed that the results will prove of interest and value.

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*Eighth An. Report N. Y. State Ag. Exp't Station, pp. 130–131.

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OF
TOBACCO CURED BY THE LEAF-CURE ON WIRE AND THE STALK PROCESSES.

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RESULTS OF CHEMICAL ANALYSES

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By F. B. CARPENTER, Assistant Chemist.

INTRODUCTION.

This bulletin is supplementary to one already published by this Station (Bulletin No. 86), entitled "Tobacco Curing by the Leaf Cure on Wire, and the Stalk Processes." It was stated in that bulletin that the object of the experiment was "to test the comparative merits of the two systems of curing tobacco for market, especially of the variety known as yellow tobacco, grown particularly in the States of North Carolina and Virginia—namely, the old-style stalk-cure, and the newer method of curing the leaves alone, pulled from the stalk as they become ripe. Though not strictly new, public attention was specially drawn to the latter plan through the efforts of Capt. W. H. Snow, of High Point, N. C., in connection with an improved curing barn advocated by him. The main point of distinction between the two systems of curing is, that in the stalk-cure, when the leaves are ripe on the stalk, the whole stalk is cut down, and, with the accompanying leaves, is cured on a stick in the old-style log-barn. In the leaf-cure system, the leaves, as they mature on the stalk, are cut off (commencing at the bottom), stuck on wires, and cured, while the stalk is still standing in the field. The cure is made either in an old-style log-barn, or, better, in a patented barn of improved construction, known as the Snow barn, which possesses principles that must commend themselves for their simplicity and scientific thoroughness."

Bulletin No. 86 dealt with the merits of the two systems with reference to the comparative values as influenced by quantity, quality, expense of management, etc., while this bulletin discusses the chemical compositions of the tobacco as cured by the two methods.

In dealing with tobacco from a chemical standpoint, we have first to consider the conditions which surround the plant during its various stages of growth, and then the changes which take place in the various processes of curing, fermentation, and manufacture. Of all the conditions which influence the quality of tobacco, there is probably none which makes more marked variations than that of climate. The plant has a widespread cultivation, extending through a wide range of territory, including portions of the tropical and temperate zones. The fine aromatic flavor, upon which the value largely depends, seems to be most properly developed in the plant by the agencies of high temperature and moisture.

Little can be done, however, to change the influences of climate, but the other conditions that must be fulfilled in order to succeed in the cultivation of the crop may be modified to produce the desired result.

The quality also depends, to a large extent, on the character of the soil. While the plant thrives best in a soil rich in fertilizing ingredients, too much organic matter tends to make the leaves coarse and heavy at the expense of quality. The finest leaves are produced on a light sand, or sandy loam, having an average amount of organic matter. The soil seldom possesses the elements of plant food in such a form as to be conducive to the production of a fine tobacco leaf. This deficiency must be supplied by the application of suitable fertilizers. Care must be exercised in the selection of the proper elements of plant food, for ingredients might be taken up by the plant which would be detrimental to its burning qualities, or other properties which give to it its value.

The various properties of the leaf are thus more or less affected by the climate, soil, fertilizers, mode of cultivation, time of harvesting, etc.

While, therefore, it is permissible to trace out the relations between Nature and the proportions of the various constituents, we must also consider the treatment to which the plant is subjected after it has been removed from Nature's laboratory, and note what effect this subsequent treatment has on the finished product. There are various processes of curing, fermenting and flavoring which affect, in one way or another, the quality and composition of the commercial article. The experiment already made only includes two of the many different processes, namely, curing by the leaf process and the stalk process.

The Constituents of Tobacco.

The constituents of tobacco are present in varied proportions in different tobaccos, and the variation is still more noticeable in the commercial article which has been subjected to the different processes of curing and manufacture. The results of chemical analysis show that the same constituents, with a few exceptions, are found to be present, to a greater or less extent, in all varieties. The constituents already identified in the leaf of the tobacco plant are as follows:

Nicotine ($C_{10}H_{14}N_2$).—This alkaloid is the active principle of tobacco. It consists of a volatile oily substance, and possesses a strong tobacco odor. It has been ascertained that nicotine is present in the largest quantities in the ripe leaf, while the percentage decreases in the young and overripe leaves. Though the narcotic effects must be partly due to this alkaloid, it cannot be said that they are wholly due to it. Some tobaccos contain little or no nicotine, yet smokers consider cigars made from this tobacco to be strong.

Nicotianine ($C_{23}H_{32}N_2O_3$).—A volatile substance of the consistency and appearance of camphor, possessing the odor of tobacco, and an acrid, aromatic, and bitter taste. It forms no compounds with acids or alkalies, and is supposed to be the substance to which the characteristic odor and flavor of tobacco are chiefly due.

Resinous and Fatty Substances.—Under this head we include the resin, wax, oil, and fat, the nature of which, as yet, little is known. These substances are present in considerable proportions in tobacco, and it is probable that the odor of the smoke is greatly influenced by them.

Starch ($(C_6H_{10}O_5)_n$).—Starch exists in tobacco, as in most plants, but in smaller proportions.

Glucose ($C_6H_{12}O_6$).—This sugar is present in small proportions in the green plant, but it is generally stated that cured tobacco contains no sugar. While this is true in many cases, there are varieties which have a large percentage of sugar, which, when cured by certain processes, nearly the entire amount remains unchanged in the leaf. Such is the case with the tobacco analyzed and reported in this bulletin. The carefully regulated drying by artificial heat has reduced the fermentation to a minimum, and left the glucose unchanged.

Nitrogenous Substances.—Nitrogen is present in small quantities in nicotine, nicotianine, ammonia, and nitric acid, but there are much larger proportions in nitrogenous organic substances. These latter are to be regarded as products altered from the original albuminous substances present in the green leaf.

Pectic acid ($C_{16}H_{22}O_{15}$) is supposed to exist in tobacco as calcium pectate. It is found in the largest proportions in the stem, and smallest in the stalk. This insoluble lime-salt, together with cellulose, gives stiffness to the leaf.

Acetic acid ($C_2H_4O_2$) is present in nearly all tobaccos in small proportions, and is probably, for the most part, the product of fermentative changes.

Malic acid ($C_4H_6O_5$) forms from six to ten per cent. of the cured leaf, while in the stalk the amount is very small.

Citric ($C_6H_8O_7$) and *Oxalic acid* ($C_2H_2O_4$) are always present in tobacco in varying but usually small proportions.

Nitric acid (HNO_3) is sometimes present to the extent of three to four per cent. of the cured leaf, while in other cases there is not a trace to be found. Nessler attributed the presence of this substance to the decomposition of other nitrogenous substances by fermentation. It is more probable, however, that the nitric acid was taken in through the roots in the process of nutrition, as will be shown in this bulletin under the head of "Nitrates in Tobacco."

Ammonia (NH_3) is always present in the cured tobacco in small proportions. It is supposed to be the product of fermentation.

Cellulose $(C_6 H_{10} O_5)_n$ forms from six to fifteen per cent. of the leaf, while the stalk contains from thirty to forty per cent. This material constitutes the frame-work of the plant, and bears an important relation to the character of the leaf. According to Nessler, the quality of tobacco for smoking increases to a certain extent as the cellulose increases, and that of the extractive substances diminish.

Organic Substances.—Substances other than those previously enumerated are present in tobacco, the nature of which has not been fully investigated. The character of some of these substances, which exist in the green plant, is entirely changed in the fermented product.

Mineral Ingredients—The proportion of mineral ingredients in the leaf varies in different tobaccos from 8 to 27 per cent., while that of the stalk is very much less. The quality of the leaf is greatly influenced by the amount and nature of the mineral constituents. These constituents consist of combinations of potash, soda, lime, magnesia, phosphoric acid, iron, alumina, silica, chlorine, sulphuric acid, and sometimes a trace of manganese. These substances are present in varying proportions in different varieties, but there are usually large percentages of potash and lime present. It is generally supposed that the presence of a large percentage of potash is beneficial for smoking purposes, while chlorine is generally considered deleterious.

METHODS OF ANALYSIS.

Tobacco analysis has received but little attention in this country, hence we have adopted no official methods of analysis. Many of the methods now in use are old, and while some are good others are quite inaccurate. It has been the purpose in selecting the methods used in this bulletin to choose those which would be of practical application, combined with simplicity and accuracy.

The basis of the following scheme of analysis is compiled from the methods of Grandeau, Schloessing, Fresenius, Nessler, Patterson, Kessling, Association of Official Agricultural Chemists, and the Sixth Annual Report of the New York Station, to which modifications and additions have been made.

ORGANIC ANALYSIS.

Preparation of Samples.—The cured leaves are stemmed, and then allowed to thoroughly dry at the temperature of the grinding-room. The two portions are then weighed, ground so as to pass through a 1-36 inch sieve, and preserved in air-tight jars. The grinding will have to be done on a very dry day, or the tobacco will become too wet to handle. The different determinations are to be made from these finely-ground air-dry samples, and the results afterwards calculated to water-free basis.

Moisture.—Two to three grams are dried for four hours, heating fully to the temperature of boiling water.

Nicotine.—Take 5 to 10 grams tobacco, and thoroughly saturate it with an alcoholic solution of soda (6 grams $NaOH$ in 40 c. c. H_2O and 60 c. c. 95 per cent. alcohol.) Allow this to stand for several hours to partially dry out and drive off the ammonia. Then transfer to an extractor and extract with ether for 8 hours, collecting the extract in a 300 c. c. flask The extract is then made slightly acid with sulphuric acid, and the ether evaporated off, using a very gentle heat. To this residue add 150 to 200 c. c. diluted soda hydrate solution (4:100), and distill off the nicotine. Titrate the distillate with $\frac{n}{10}$ sulphuric acid, cochineal being used as an indicator. Forty-nine (49) parts by weight of H_2SO_4 being equal to 162 parts by weight of nicotine.

Nitric acid (*Qualitative*).—The qualitative test is made as follows: Two or three grams of the substance are placed in a beaker, thoroughly mixed with a small amount of water, and allowed to stand for a short time. This is then filtered off, and a few drops are placed on a porcelain crucible cover; a few drops of concentrated sulphuric acid, in which some brucine has been dissolved, is now brought on the cover, and the two solutions are allowed to mix. If a bright-red color is formed where the two solutions meet, then nitric acid is present. This is a very delicate test, and, if properly handled, is very satisfactory.

Nitric acid (*Quantitative*).—Use the Tiemann-Schultze method as described by Fresenius (Quantitative Chemical Analysis, p. 473). It is, however, more convenient to use a nitrometer according to Schiff, or some other convenient form, and the tobacco may be weighed and transferred directly to the flask, the amount taken to be varied according to the amount of nitric acid present.

Total Nitrogen.—Determine by the Kjeldahl method of the Association of Official Agricultural Chemists (Bulletin 31, Division of Chemistry, U. S. Department of Agriculture, p. 184).

Ammonia.—Weigh out 10 grams of tobacco, and transfer to a Kjeldahl distillation flask. To this add 200 c. c ammonia-free water and 1 to 2 grams of recently ignited magnesia; distill this solution until the distillate is no longer alkaline, catching the distillate in very dilute sulphuric acid. Precipitate the nicotine in this solution with mercurio-potassic iodide. Filter, and wash thoroughly with water. Add sufficient potassium sulphide to the filtrate and washings to precipitate the excess of mercury; then make alkaline with sodium hydrate, and distill off the ammonia, catching it in $\frac{n}{10}$ sulphuric acid. Determine the ammonia by titration.

Albuminoids.—The nitrogenous substances termed albuminoids are found by multiplying by 6.25 the residue left on deducting from the total nitrogen, the nitrogen contained in the nicotine, ammonia and nitric acid.

Ether Extract.—Place 2 grams of water-free tobacco in an extractor and extract for 24 hours with anhydrous ether. Evaporate off the ether, dry and weigh. This long continued extraction with ether is found to take out nearly all of what would be termed resinous or fatty substances. An additional extraction with absolute alcohol will remove what has not been removed by the ether. This residue must, however, be washed with water, as the alcohol removes other substances besides the resins. A few experiments made by extracting with both ether and alcohol, washing the residues with water, drying, and weighing, gave nearly the same results as the ether extract alone without washing the residue. The extraction with alcohol being somewhat difficult to manage, it was thought preferable, for the comparison in this bulletin, to extract with ether alone.

Cellulose.—Proceed according to method for crude fiber, Bulletin 31, U. S. Dept. Agr., Div. of Chem., p. 190.

Pectic Acid.—Weigh out 2 grams tobacco and transfer to a filter, wash slowly with 80 per cent. alcohol, with which one-fourth the quantity of concentrated hydrochloric acid has been mixed. When the filtrate contains no further trace of lime, the acid is completely washed out with 80 per cent. alcohol. By this method the pectic acid is separated without any loss. The substance is now transferred to a 500 c. c. Erlenmeyer flask, which is filled to three-fourths of its capacity with distilled water. To this solution add at least 2 grams of oxalate of ammonia to each gram of pectic acid, and heat in a water-bath at 35° C. for three to four hours. Oxalate of ammonia, like other salts of organic acids, has the property of dissolving pectic acid. Furthermore, this solution is much easier to filter than an alkaline pectic acid solution. After filtering and washing, precipitate the filtrate with acetate of lime in excess. The precipitate consists of oxalate and pectate of lime, from which the pectic acid can be separated by washing slowly with alcohol strongly acidified with hydrochloric acid. This operation may be avoided if one has weighed the amount of oxalate of ammonia used. In this case filter the oxalate and pectate of lime on tared filters; wash with water, then with alcohol; dry at 100° C. and weigh. Now calcine the precipitate obtained, deduct the amount of lime which was combined with the oxalate of ammonia employed, and the residue is the lime combined with the pectic acid. The oxalate and pectate of lime, minus the oxalate of lime, gives the pectate of lime and this, minus the lime combined with it, gives the pectic acid.

Glucose.—Five to ten grams of the substance are placed in a beaker, with a small amount of water, and allowed to stand for 1 or 2 hours. Filter, and wash until all the glucose is removed. This is generally accomplished when the filtrate and washings amount to 200 c. c. Treat this solution with a slight excess of basic acetate of lead; filter, and wash thoroughly. Remove the excess of lead with sodium carbonate, and determine the glucose in an aliquot part of this solution with Fehling's solution.

Starch.—The residue from the preceding determination is placed in a flask of 250 c. c. capacity, 150 c. c. of distilled water, 4 to 5 c. c. of concentrated hydrochloric acid added, and the flask closed by a cork having a small glass tube, about three feet long, inserted in it to act as a condenser. The flask is then put in a water-bath, and kept at the temperature of boiling water for twelve hours. The flask is allowed to stand over night; the solution is then filtered off, the filtrate neutralized with sodium carbonate, and the washing continued until all the glucose is washed out, which is generally accomplished when the filtrate and washings amount to 200 c. c. The gluclose is then determined by Fehling's solution, as in the preceding case, and the starch calculated from the result.

Acetic Acid.—The solubility of acetic acid salts in water and alcohol precludes the use of the precipitation method of estimating this acid. But acetic acid is volatile, and this peculiarity may be advantageously employed to furnish a very simple method for separating it. Use a stream of steam to volatilize the acetic acid, which has been previously freed from its bases by a stronger non-volatile acid. A convenient apparatus for this determination consists of a glass cylinder 2 to $2\frac{1}{2}$ inches in diameter and 15 inches long, having the ends contracted so as to receive rubber stoppers. This is clamped in a retort stand at an angle of about 45°; the lower end is connected with a glass tube, which dips in a jar of water. In the upper end is inserted a rubber stopper with two holes. One hole is connected by a glass tube with a distillation flask. A glass tube passes through the other hole, which is connected with a Kjeldahl condenser on the outer end, while the inner is attached by means of a rubber stopper, with a glass cylinder about 6 inches long and $1\frac{1}{2}$ inches in diameter, having the ends slightly contracted. Three to five grams of finely pulverized tobacco are wet with a few c. c. water, to which a little finely pulverized tartaric acid has been mixed. This is placed in the inner cylinder between two layers of loose cotton wool, or, better, glass wool. The distillation flask is now partly filled with water and boiled until the distillate is no longer acid. Twenty to thirty minutes is usually long enough to separate all the acid. The steam passes from the flask into the outer cylinder, then through the material in the small cylinder to the condenser, carrying the acetic acid with it. It is here condensed and collected in distilled water, allowing the lower end of the condenser to dip in the water. The distillation having been completed, the acetic acid is determined with $\frac{n}{10}$ standard alkali, using phenolthaline as an indicator. The outer cylinder plays a very important part in this determination, as it keeps the inner tube the same temperature on the outside as inside, thus preventing the steam from condensing while passing through the tobacco. The steam which is condensed in the outer tube is collected in the jar of water at the lower end.

Oxalic, Citric, and Malic Acids.—The solution of these acids and their salts in tobacco could be obtained with acidified water or alcohol, but both these mediums dissolve, also, other substances from which the separation of the acids is very difficult. It is, therefore, desirable that the exhaustion be conducted with ether, which, in general, dissolves neither mineral salts nor albuminous substances. The employment of ether requires that the organic acids be liberated by the use of some stronger acid, as, for example, sulphuric acid. Examine first the ash of the substance, so that the minimum amount of sulphuric acid can be calculated, which the bases, not combined with mineral acid, require. The ash of tobacco, for instance, may contain 60 per cent. carbonate of lime, 10 per cent. carbonate of potash and 5 per cent. carbonate of magnesia. This would require 64 per cent. SO_3. If, therefore, we have 10 grams of substance for the extraction, the ash will weigh 2 grams, and will require a minimum of 1.3 gr. SO_3. To insure the freeing of the organic acids it is customary to use double the minimum amount, or, in this case, 2.6 gr. of SO_3. Care must be observed not to use more than this proportion, as it might be carried over with the ether, and would cause trouble in the different determinations. After the sulphuric acid is diluted with four to five times its weight of water, the proper amount is poured on 5 to 10 grams of tobacco, and thoroughly mixed in a mortar; work the mass lightly to remove the sap, then mix with a small quantity of pumice stone; transfer the whole to a Soxhlet extractor, and subject it to a continuous extraction with ether for at least 15 hours. The operation is considered complete when a few drops, caught from the outlet of the extractor, evaporate readily, showing that there is no acid to hinder the evaporation. The ether removes neither the nitric, hydrochloric, or sulphuric acids, but completely all traces of phosphoric acid. Evaporate the ether until there is but a few c. c. left in the flask, then add a few c. c. of water, and mix very slowly with the etherial fluid to insure the complete solution of the acids. Finally transfer to a beaker, and wash thoroughly. Unite the wash-water with the solution in the beaker, and evaporate the ether at the lowest possible temperature. The solution is now ready for the determination of the organic acids.

Oxalic Acid.—Neutralize with ammonia, make slightly acid with acetic acid, and precipitate the oxalic acid with a dilute solution of acetate of lime, avoiding an excess, since it would interfere with the other determinations. After the oxalic acid is completely separated filter, wash thoroughly, ignite, and weigh. The percentage of oxalic acid is calculated from the lime thus obtained.

Citric Acid.—The filtrate from the preceding determination is made very slightly acid with acetic acid. Now add slowly, with constant stirring, a dilute solution of acetate of lead until a permanent precipitate appears. When the supernatant liquid is clear draw off a few c. c. by means of a pipette, and transfer to a small beaker. To this solution add a few drops of acetic acid and a small amount of a very dilute solution of acetate of lead, and observe from this portion of the liquid whether a permanent precipitate can be obtained, or whether it dissolves again in the acetic acid. In the first case we must continue to add acetate of lead to the original solution and again test a small portion, and so continue until we get a sample in which the precipitate redissolves in acetic acid. At this moment the citric acid is completely precipitated. The samples taken out to test must be neutralized with ammonia, and washed back into the original solution. Let stand for a few hours. filter on a tared filter, wash first with water to which a few drops of acetate of lead and acetic acid have been added, then with 80 per cent. alcohol, and conclude the washing with a mixture of equal parts of water and alcohol. Dry the precipitate, weigh, ignite at a low heat in porcelain crucible, and weigh again. The loss in weight is counted as citric acid. In the filtrate, under the influence of the alcohol, the small portion of citrates still in solution separates and falls with the malates. These are filtered out, washed with alcohol, dried, ignited, weighed, and calculated as half citrate and half malate of lead. The conjoint weight of both acids is so small that the error that might arise from this source is very small.

Malic acid.—The alcohol is evaporated off from the last filtrate. When this has been completed the liquid is agitated with acetic acid in excess, and a sufficient amount of acetate of lead having been added, the whole is overflowed with 5 to 6 volumes of 80 per cent. alcohol, containing .005 parts acetic acid. The malate of lead separates completely as neutral salt. After standing for 12 or 15 hours filter, wash, dry, weigh, ignite in a porcelain crucible, and weigh as oxide of lead. The loss of weight by ignition is the weight of the malic acid. The organic matter which is mingled with these precipitates is usually so small that it need not be considered. The phosphoric acid is precipitated as phosphate of lead, and comes down with the citrate of lead. This amounts to but a few milligrams, and may be estimated by dissolving the lead oxide after ignition with acetic acid, and deducting what remains from the total weight. This method for extracting these acids, although not all that could be desired, gives fairly good results if carefully managed. It is more satisfactory than any other method that was tried.

Crude ash.—Char 2 to 3 grams of substance at the lowest possible red heat in a muffle, and burn until white, or when by further burning there appears to be no change in the appearance of the ash, taking care not to have heat enough to fuse it.

ASH ANALYSIS.

The ash is burned in the same manner as for the determination of crude ash, thoroughly pulverized in an agate mortar, and preserved in bottles fitted with rubber stoppers.

Solutions.—One gram of ash is weighed into a 6 oz. beaker, and a little water added, covered with a watch glass, and HCl added cautiously until effervescence ceases, then a few drops of HCl added in excess, and the whole evaporated to dryness. The residue is then moistened with HCl, water added and heated on a water-bath for a few minutes, then filtered through a tared Gooch crucible. The residue (sand, silica and carbon) is dried, weighed and ignited. The loss is taken as carbon, and the remainder as sand and silica. The filtrate is made up to 200 c. c. and used in the following determinations:

Sulphuric acid.—Fifty cubic centimeter of the filtrate is made up to 100 c. c. or more, heated to boiling, a boiling solution of barium chloride added, and heated until the supernated liquid is clear; then filtered, washed, dried, ignited, and weighed. The precipitate is barium sulphate, from which the SO_3 is calculated.

Alkalies.—The filtrate from the above is heated to boiling, a slight excess of barium chloride is added drop by drop with constant stirring; without filtering, and in the same manner barium hydrate is added in slight excess. Heat, filter, and wash until precipitate is free of chlorides. Add to the filtrate 1 c. c. of ammonia, and then a saturated solution of ammonium carbonate until the excess of barium is precipitated. Heat, add now, in fine powder, 0.5 grams pure oxalic acid. Filter, wash free of chlorides; evaporate the filtrate to dryness in a platinum dish, ignite carefully over a free flame below red heat until all volatile matter is driven off. Digest the residue with hot water with a few drops of HCl, filter through a small filter, wash, evaporate filtrate to dryness in a tared platinum dish. Ignite gently at low red heat, and weigh as total alkalies.

Potash.—The residue from the above is taken up with a few drops of HCl and hot water; enough platinic chloride is added to precipitate the chlorides; evaporate until the solution crystalizes upon cooling, treat with 80 per cent. alcohol, wash by decantation, collect in a Gooch crucible, wash with strong alcohol, dry at 100° for thirty minutes, and weigh as $K_2 Pt Cl_6$.

Soda.—Soda is determined by difference between potash and total alkalies.

Lime.—Fifty cubic centimeters of the original solution are made alkaline with ammonia, then acetic acid is added in excess; filter and wash thoroughly. The filtrate is heated nearly to boiling, and ammonia oxalate added in slight excess; continue to heat until the supernated liquid is clear; filter, wash, dry, ignite intensely, and weigh as CaO.

Magnesia.—The last filtrate is made alkaline with ammonia, sodium phosphate added, and allowed to stand for some time; filter, wash with weak ammonia, dry, ignite, and weigh as $Mg_2P_2O_7$.

Phosphoric acid.—Take 50 c. c. of the original solution, neutralize with ammonia, then make slightly acid with nitric acid, add 50 c. c. (more if necessary) molybdic solution, and keep for one hour at the temperature of 65° C. Filter, and wash with ammonium nitrate solution. This filtrate is used for the determination of iron and alumina, described in the next paragraph. The precipitate is dissolved on the filter with dilute ammonia and hot water; the filtrate is nearly neutralized with HCl, and 10 c. c. magnesia mixture is added slowly, with constant stirring: after fifteen minutes add 25 c. c. strong ammonia, and let stand for 2 hours or more; filter, wash with dilute ammonia, ignite, and weigh as $Mg_2P_2O_7$.

Iron and alumina.—The filtrate from the precipitate of ammonium phospho-molybdate is cautiously neutralized with ammonia, care being taken that the temperature does not rise above 40° C., and that the ammonia is only in slight excess. Allow to stand in a warm place until the precipitate completely settles; filter the supernatant liquid, wash the precipitate by decantation, then transfer it to a filter and complete the washing. Redissolve the precipitate in weak nitric acid, reprecipitate, filter, wash, dry, ignite, and weigh as ferric oxide and alumina.

Ferric Oxide.—Dissolve the precipitate of ferric oxide and alumina, reduce with zinc, and determine the ferric oxide with a standard solution of potassium permanganate.

Alumina.—The combined weight of ferric oxide and alumina, minus the ferric oxide obtained, gives the weight of alumina.

Chlorine.—Weigh 5 grams of ash into a beaker, add 100 c. c. of water and a little nitric acid, let stand for one hour, filter, wash, neutralize the filtrate with sodium carbonate, and determine the chlorine with a standard solution of silver nitrate, with the aid of yellow chromate of potash.

Carbonic acid.—One gram of the ash is weighed into a Shepard alkalimeter, a little water added, and the carbonic acid freed with dilute nitric acid, with the aid of a gentle heat, the loss being the carbon dioxide. This method, if properly manipulated, is highly satisfactory.

Insoluble silica, or sand.—Weigh 1 gram into a beaker, add a small quantity of water and hydrochloric acid in excess, heat for some time on a water-bath, filter through a tared Gooch crucible, ignite, and weigh as SiO_2 or sand.

Soluble silica.—The total silica obtained by bringing the solution to dryness before filtering, minus the insoluble silica, gives the soluble silica.

OCCURRENCE OF NITRATES IN TOBACCO.

In nearly all varieties of tobacco a part of the nitrogen is found to exist in the form of nitrate. Just how this form of nitrogen finds its way into the plant has been a disputed question. Some authorities claim that it is a product of decomposition, and the amount may be regulated, to a certain extent, in the process of curing, while others claim that it is taken directly into the plant from the soil through the roots in the process of nutrition, where part or all of it is decomposed to form the other nitrogenous compounds of the plant. From the results of analyses given in the accompanying table it will be seen that the latter theory is more plausible.

The tobacco used in the analyses was the ordinary "bright tobacco" peculiar to certain portions of North Carolina. The seed were sown in the seed-bed, and the plants were transplanted in the field when of proper size. Samples were taken from time to time, commencing at the time the plants were transplanted, and analyses made of the different samples, giving the percentage of nitrogen as nitrate, together with the other forms of nitrogen existing in the different parts of the plant at the different stages of growth. From an inspection of the table it will be noticed that the nitrates are confined almost entirely to the stalk and stems in the younger growth of the plant, while the other nitrogenous substances are more abundant in the leaves. This would indicate that the nitrates had been taken into the plant in the process of nutrition, and used to form the nitrogenous compounds of the rapidly-growing plant, while later the larger plant seems to have consumed the nitrates as fast as they were supplied. These facts lead to one of two conclusions: either the nitrates have, in some mysterious way, passed out of the plant, or the more rational conclusion that the nitrates have been decomposed to form other nitrogenous compounds. In this experiment we have no indication of nitrates being found in the mature tobacco from decomposition in the process of curing. Unfortunately, however, this variety of tobacco is exceedingly free from nitrates as compared with other varieties, as will be seen from the analysis of stems of other varieties.

The methods of analysis used in Table I are those in ordinary use. The total nitrogen was determined by the Kjeldahl method as modified by Scovell to include nitrates. The nitrogen existing as nitrate was determined by the Tiemann Schultze method. The nitrogen existing as nitrate, subtracted from the total nitrogen, gives the organic or nitrogen not in the form of nitrate. All analyses are calculated to the air-dry sample.

TABLE I. EXISTENCE OF NITRATES IN YELLOW TOBACCO AT DIFFERENT STAGES OF GROWTH.

Station No.	Part of Plant.	Where Sampled.	When Sampled.	Per ct. Nitrogen existing as Nitrate.	Total Nitrogen not existing as Nitrate.
6007	Roots	From plant-bed	May 29, 1889	None.	2.32
6008	Stalks	“ “	“ “	0.15	1.83
6009	Leaves	“ “	“ “	None.	4.22
6010	Stems	“ “	“ “	0.22	2.11
6011	Roots	From field	June 27, 1889	0.07	2.04
6012	Stalks	“ “	“ “	0.51	2.01
6013	Leaves	“ “	“ “	0.09	5.56
6014	Stems	“ “	“ “	0.77	1.87
6015	Leaves (primed)	“ “	“ “	None.	3.82
6016	Stems (primed)	“ “	“ “	0.51	1 43
6017	Roots	“ “	July 11, 1889	None.	1.38
6018	Stalks	“ “	“ “	None.	1.01
6019	Leaves	“ “	“ “	None.	2.71
6020	Stems	“ “	“ “	None.	0.99
6021	Leaves (primed)	“ “	“ “	None.	1.95
6022	Stems (primed)	“ “	“ “	None.	1.04
6023	Tops	“ “	“ “	------	4.50
6024	Suckers	“ “	July 27, 1889	None.	3.95
6025	“	“ “	Aug. 12, 1889	None.	3.57
6026	“	“ “	Aug. 31, 1889	None.	3.04
6027	Roots	“ “	Sept. 2, 1889	None.	0.99
6028	Stalks	“ “	“ “	0.03	0.88
6029	Leaves	“ “	“ “	None.	1 94
6030	Stems	“ “	“ “	None.	0.69
6031	Roots	From barn	Sept. 9, 1889	None.	1.17
6032	Stalks	“ “	“ “	Trace.	1.41
6033	Leaves (smokers)	“ “	“ “	None.	1.98
6034	Stems “	“ “	“ “	None.	0.69
6035	Leaves (tips)	“ “	“ “	None.	1.93
6036	Stems “	“ “	“ “	None.	0.93
6037	Leaves (fillers)	“ “	“ “	None.	2.17
6038	Stems “	“ “	“ “	None.	0.80
6039	Leaves (cutters)	“ “	“ “	None.	2.01
6040	Stems “	“ “	“ “	None.	0 80
6550	Seed	------------------	----------------	None.	3.36
6553	Second growth	------------------	----------------	None.	1.55

Following is a table (II) giving the percentage of both organic and nitric nitrogen in a few samples of tobacco stems analyzed at the Station. It will be observed that the North Carolina stems are very low in nitrates, while the other varieties contain a considerable amount. The percentages of phosphoric acid, and the soluble and insoluble potash are included as matters of interest.

TABLE II. ORGANIC AND NITRIC NITROGEN IN TOBACCO STEMS.

Station Number.	TOBACCOS.	Moisture.	Volatile and Organic Matter.	Crude Ash.	Per ct. Phosphoric Acid.	Per ct. Water Soluble Potash.	Per ct. Total Potash.	Per ct. Water Sol. in Total Potash.	Nitrogen existing as Nitrate.	Total Nitrogen not existing as Nitrate.
5900	Missouri stems for chewing tobacco	16.56	61.65	21.79	.82	8.44	9.08	92.95	0.83	1.69
5901	Kentucky stems for chewing tobacco	16.85	61.69	21.46	.72	8.36	8.89	94.04	0.72	1.66
5902	Ohio stems for chewing tobacco	15.70	62.17	22.13	.84	8.11	8.56	94.63	0.60	2.26
5903	Virginia stems for shipping or export tobacco	16.20	63.72	20.08	.56	6.35	7.00	90.71	0.54	2.05
5904	Virginia stems for shipping or export tobacco	17.15	63.80	19.05	.43	5.25	5.63	93.25	0.13	1.64
5905	North Carolina stems for cigarettes	18.18	65.86	15.96	.51	4.97	5.33	93.15	0.00	0.77
5906	North Carolina stems for cigarettes short	15.90	65.80	18.30	.58	4.11	4.19	98.09	0.15	1.26
5907	Stalk of bright N. C. tobacco	17.36	71.78	10.86	.52	3.92	4.34	90.32	0.05	1.68
5923	North Carolina stems for chewing tobacco before casing	16.75	67.40	15.85	.73	3.37	3.66	92.08	0.00	.98
5924	North Carolina stems for chewing tobacco after casing*	12.42	70.29	17.29	.43	4.27	4.55	93.84	0.07	1.43
5926	North Carolina dust from smoking tobacco factory, poor sample	9.04	48.68	42.28	.87	1.67	1.97	84.77	0.00	1.23

*This sample being wet when received, was air-dried, which accounts for the increased percentage.

DESCRIPTION OF THE TOBACCO SOIL.

The soil upon which this tobacco was grown is a light-gray sand, with porous cream-colored subsoil. This soil belongs geologically to the Laurentian series of the Archæan era, which formation seems to be peculiarly adapted for the production of the yellow tobacco for which Granville county, N. C., has become famous. The tobacco soil, the analysis of which is given below, was not from the same field in which the experiment tobacco grew, yet was from the same locality, about two miles distant, and represents very closely the general character of the best bright tobacco soil. This sample was taken from a field of about 30 acres, owned by Mr. J. M. Currin, Oxford, N. C.

The land was cleared about ten years previous and was cultivated for four or five years, since which time it has not been in cultivation until the summer of 1892, when a fine crop of tobacco was grown. The fertilizers used on the soil for this crop consisted of a light coat of stable manure and 1,000 pounds of commercial fertilizer to the acre. Mr. Currin considers this a typical tobacco soil:

	Top soil.	Subsoil.
Coarse materials	7.05	3.95
Fine earth	92.95	96.05
	100.00	100.00
Analysis of Fine Earth:		
Insoluble matter	95 642	94.870
Soluble silica	.938	1.476
Potash (K_2O)	.161	.057
Soda (Na_2O)	.109	.232
Lime (CaO)	.240	.265
Magnesia (MgO)	.047	.056
Peroxide of iron (Fe_2O_3)	.326	.488
Alumina (Al_2O_3)	1.038	1.872
Phosphoric acid (P_2O_5)	.016	.000
Sulphuric acid (SO_3)	.055	.072
Water (H_2O)	.312	.286
Volatile matter	1.510	1.050
	100.394	100.724

ORGANIC ANALYSES IN DETAIL.

The plans and details of the experiment for comparing the curing of tobacco by the leaf-cure and the stalk-cure, and also the results with reference to the amount and value of the tobacco as affected by the two methods of curing, were fully set forth in Bulletin 86. For convenience, the tables giving the amount and money value of each grade from each method of curing, is here reprinted.

TABLE III. RESULT OF THE EXPERIMENT.

1.—*Tobacco Curing on the Stalk from Half-acre.*

MARK.	GRADE.	Weight in Pounds.	Value, Estimated by Experienced Buyers, Per 100 Pounds.						Actual Sale.	Total Value.
			Z. W. Lyon.	J. G. Hunt.	E. T. White.	J. M. Currin.	J. H. Bullock.	Av. of the five.		
	Smokers.									
A	Scrap from stalk	6.50	$ 3.50	$ 4.00	$ 4.00	$ 5.00	$ 4.00	$ 4.10	$ 4.00	$ .2665
C	Scrap	15.75	2.50	3.00	2 50	3.00	2.75	2.75	3.00	.4331
D	Trash lug	49.	3.50	5.00	3.40	4.00	5.00	4.18	4.00	2.0482
F	Best lug	18.75	10.00	10.00	9.00	8.00	8.00	9.00	9.00	1.6875
	Cutters.									
I	Sand lug	63.75	15.50	14.00	16.00	15.00	12.00	14.50	14.00	9.2437
K	Best lug	16.75	15.00	17.00	15.00	15.00	15.00	15.40	20.00	2.5795
	Wrappers.									
M	First grade	50.	18.00	20.00	16 00	18.00	20.00	18.40	14.25	9.2000
N	Second grade	54.	13.50	15.00	14 00	13.00	14.00	13.90	13.00	7.5060
	Fillers.									
P	Bright tips	47.	10.00	12.00	10.75	9.00	11.00	10 55	10.75	4.9585
S	Black tips	4.75	7.75	9.00	7.00	7.50	7.50	7.75	9.00	.3681
	Total	326.25	Average value per 100 pounds, $11.74.						Total	$38.29

2.—*Tobacco Curing by the Leaf Process on Wire from Half-acre.*

MARK.	GRADE.	Weight in Pounds.	Value, Estimated by Experienced Buyers, Per 100 Pounds.						Actual Sale.	Total Value.
			Z. W. Lyon.	J. G. Hunt.	E. T. White.	J. M. Currin.	J. H. Bullock.	Av. of the five.		
	Smokers.									
B	Scrap	13.50	$ 3.00	$ 3 20	$ 3.50	$ 3.00	$ 3.00	$ 3.14	$ 3.10	$ .4239
E	Trash lug	34.75	6.00	6.00	5.00	5 00	6.00	5.60	6.00	1.9460
G	Best trash lug	31.75	12.50	12.50	12.50	12.00	10.00	11.90	12.00	3.7782
	Cutters.									
H	Sand lug	104.	16 50	16.00	17.50	14.00	16.00	16.00	16.75	16.6400
J	Best lug	40.	15.00	18.00	17.00	18.00	15.00	16.60	20.00	6.6400
	Wrappers.									
L	First grade	90.	20.00	20.00	20.00	20.00	22.00	20.40	20.00	18.3600
O	Second grade	55.	11.50	16.00	16 00	12.00	14.00	13.90	14.00	7.6450
	Fillers.									
Q	Bright tips	56.25	8.25	12.00	10.00	11.00	8.00	9.85	9.25	5.5406
R	Black tips	28.75	7.00	8.50	8.00	7.00	7.00	7.50	7.50	2 1663
	Total	454.	Average value per 100 pounds, $13.91.						Total	$63.14

Having thus compared in a commercial way the two methods of curing, it was thought desirable to continue the experiment, and see if there was any material difference in the chemical composition of the two lots of tobacco resulting from the two processes. Samples were taken from each grade mentioned in the preceding table, packed in a tight box, and sent to the laboratory. The stems were then separated from the leaf, and the samples allowed to become thoroughly air-dry on a dry day. These samples (stems and leaves separately) were ground until they would pass a No. 36 sieve, and preserved in tight jars for analysis. Partial analyses were made of all the samples representing the different grades, and more complete analyses of a few samples representing the same grade by both processes of curing.

The following tables give the results of the analyses, which are tabulated in such a way as to admit of easy comparison:

TABLE IV. ANALYSES OF WHOLE TOBACCO LEAVES (AIR-DRIED). CALCULATED FROM THE DIRECT ANALYSES OF MIDRIB AND LEAVES (EXCLUSIVE OF MIDRIB).

1. *Cured by the Stalk Process.*

MARK.	GRADE.	Leaf without stem.	Stems.	Whole leaf	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid	Ammonia.	Cellulose.	Moisture.	Ash.	Sand.	Ash exclusive of sand
		Pr Ct	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*	*Pr Ct*
	Smokers.													
A	Scrap from stalk	----	----	----	2.53	9.45	9.06	0	.122	9.28	6.19	14.37	2.79	11.58
C	Scrap	86.1	13.9	100	1.80	6.88	5.92	0	.107	9.38	6.88	18.58	7.11	11.47
D	Trash lug	80.6	19.4	100	1.84	6.73	5.03	0	.118	9.66	9.14	14.46	1.87	12.59
F	Best lug	78.	22.	100	1.85	6.70	5.90	0	.099	9.27	8.74	12.65	1.23	11.42
	Cutters.													
I	Sand lug	80.	20.	100	2.16	7.64	6.07	0	.107	8.89	6.58	12.42	.38	12.04
K	Best lug	80.6	19.4	100	2.43	6.88	5.80	0	.100	8.80	7.42	11.87	.40	11.47
	Wrappers.													
M	First grade	79.6	20.4	100	2.48	6.65	6.38	0	.116	8.55	8.84	11.32	.44	10.88
N	Second grade	81.2	18.8	100	2.49	6.77	6.20	0	.113	8.61	8.06	11.03	.31	10.72
	Fillers.													
P	Bright tips	83.2	16.8	100	2.49	7.08	7.01	0	.127	8.40	8.76	9.87	.73	9.14
S	Black tips	79.4	17.9	100	1.86	6.56	7.39	0	.109	8.63	7.56	9.83	.54	9.29
W*	Leaves for comparis'n	79.	21.	100	2.31	6.24	6.81	0	.102	7.93	7.47	10.83	.23	10.60

2. *Cured by the Leaf Process on Wire.*

MARK.	GRADE.	Leaf without stem.	Stems.	Whole leaf	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid	Ammonia.	Cellulose.	Moisture.	Ash.	Sand.	Ash exclusive of sand
	Smokers.													
B	Scrap	82.7	17.3	100	1.90	5.24	5.92	0	.125	9.84	7.68	22.23	9.62	12.61
E	Trash lug	78.3	21.7	100	1.75	5.66	5.31	0	.109	9.38	7.52	18.72	5.51	13.21
G	Best trash lug	80.3	19.7	100	1.91	6.33	6.32	0	.126	8.90	8.47	15.08	3.13	11.95
	Cutters.													
H	Sand lug	82.5	17.5	100	2.05	6.35	6.59	0	.122	8.88	7.81	14.12	2.67	11.45
J	Best lug	78.6	21.4	100	2.00	6.41	6.44	0	.119	8.54	8.46	13.68	1.90	11.78
	Wrappers.													
L	First grade	79.9	20.1	100	2.18	6.16	5.97	0	.141	8.76	7.95	14.02	2.81	11.21
O	Second grade	82.6	17.4	100	2.55	6.22	8.15	0	.127	8.99	9.49	11.50	.50	11.00
	Fillers.													
Q	Bright tips	83.2	16.8	100	2.60	6.35	8.82	0	.148	8.79	8.27	10.07	.36	9.71
R	Black tips	82.1	17.9	100	2.60	4.96	10.10	0	.161	8.44	9.54	11.05	.46	10.59
X*	Leaves for comparis'n	78.1	21.9	100	2.24	5.88	6.67	0	.119	7.88	8.19	10.37	.21	10.16

*For descriptions of samples "X" and "W" see page 23.

It will be observed from the tables that the lower grades by the leaf-cure contained a much larger amount of sand than those by the stalk-cure. This is due to the fact that these lower grades are the leaves nearest the ground, and naturally collect sand by the action of rain upon the soil adjacent to the leaves. They were all pulled by the leaf process as they ripened, while in the stalk process many of the lower leaves, together with the sand contained on them, had fallen off before the time for harvesting. This inequality in the percentage of sand made it necessary to calculate the samples to a sand-free as well as water-free basis for a full comparison. (See tables V, VI and VII.) Table VII combines the two preceding tables, and presents, by calculation, the composition of the whole leaf, including midrib.

TABLE V. ANALYSES OF TOBACCO LEAVES (EXCLUSIVE OF MIDRIB) REDUCED TO A SAND-FREE AND WATER-FREE BASIS.

Station No.	Grade Mark	GRADE OF LEAVES.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
		1.—Cured by the Stalk Process.							
1	A	*Smokers*—Scrap from stalk	2.78	10.38	9.32	0	.134	10.18	12.72
3	C	Scrap	2.32	8.80	6.85	0	.139	9.15	12.86
4	D	Trash lug	2 42	8 76	6.19	0	.146	8.70	12.92
6	F	Best lug	2.49	8.85	7.29	0	.117	7.54	11.32
9	I	*Cutters*—Sand lug	2.78	9.63	7.28	0	.123	7.30	11.67
11	K	Best lug	3.14	8.75	6.72	0	.112	7.01	11.16
13	M	*Wrappers*—First Grade	3.24	8.35	7.60	0	.131	7.09	10.60
14	N	Second Grade	3.22	8.71	7.21	0	.130	8 68	10.46
16	P	*Fillers*—Bright tips	3.20	9.04	8.20	0	.149	7,09	9.13
19	S	Black tips	2.39	8.23	8.67	0	.123	6.92	8.91
20	W	Leaves for comparison	3.02	8.18	8.15	0	.121	6.34	9.69
		2.—Cured by the Leaf Process on Wire.							
2	B	*Smokers*—Scrap	2 67	7.19	7.46	0	.162	10.16	14.73
5	E	Trash lug	2.41	7.74	6.41	0	.132	8.66	13.92
7	G	Best trash lug	2.56	8.50	7.78	0	.152	8.01	12.54
8	H	*Cutters*—Sand lug	2.65	8.26	7.86	0	.143	8.13	11.78
10	J	Best lug	2.72	8.55	7.87	0	.141	7.36	11.93
12	L	*Wrappers*—First grade	2.96	8.25	7.17	0	.167	7.30	11.07
15	O	Second grade	3.32	8.00	9.87	0	.149	7.81	11.14
17	Q	*Fillers*—Bright tips	3.30	7.97	10.42	0	.171	7.68	9.65
18	R	Black tips	3.35	6.36	12.31	0	.192	7.39	10.63
21	X	Leaves for comparison	2.96	7.79	7.82	0	.146	6.46	9.07

TABLE VI. ANALYSES OF TOBACCO STEMS (OR MIDRIB) REDUCED TO A SAND-FREE AND WATER-FREE BASIS.

Station No.	Grade mark	GRADE OF LEAVES.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
		1.—Cured by the Stalk Process.							
22	A	*Smokers*—Scrap from stalk	--	----	----	-	----	-----	-----
24	C	Scrap	.73	3.36	6 86	0	.045	21.13	16.24
25	D	Trash lug	.61	2.70	3.41	0	.081	19.64	19.10
27	F	Best lug	.54	2 48	3.90	0	.084	20.05	17.48
30	I	*Cutters*—Sand lug	.48	2.51	4.08	0	.083	18.63	18.04
32	K	Best lug	.52	2.10	4.52	0	.094	20.07	17.77
34	M	*Wrappers*—First grade	.72	3.32	4.82	0	.114	18.53	17.41
35	N	Second grade	.54	1.67	4.82	0	.094	20.39	17.02
37	P	*Fillers*—Bright tips	.64	1.93	5.45	0	.101	20.13	15.03
40	S	Black tips	.64	2.98	5.57	0	.106	18.88	14.70
41	W	Leaves for comparison	.53	1.41	4 45	0	.070	17.06	18.13
43		Stalks from plants	.77	.96	8.21	0	.118	29.35	8.74
		2.—Cured by the Leaf Process on Wire.							
23	B	*Smokers*—Scrap	.72	2.67	5.52	0	.102	19.40	17.46
26	E	Trash lug	.64	2.27	4.92	0	.106	18.10	19.17
28	G	Best trash lug	.57	1.90	4.49	0	.108	18.20	17.58
29	H	*Cutters*—Sand lug	.58	1.78	4.99	0	.110	18.25	17.48
31	J	Best lug	.49	2.08	4.66	0	.101	17.46	17.47
33	L	*Wrappers*—First grade	.49	1 74	4.72	0	.120	19.57	18.42
36	O	Second grade	.54	1.74	5.21	0	.104	20.28	17 38
38	Q	*Fillers*—Bright tips	.63	1.86	5.82	0	.119	19.22	15.52
39	R	Black tips	.71	1.57	6.21	0	.119	19.08	16.98
42	X	Leaves for comparison	.57	1.48	5.32	0	.078	16.27	18.32
44		Stalks from plants	.77	.82	7.21	0	.099	31.20	9.31

TABLE VII. ANALYSES OF WHOLE TOBACCO LEAF (INCLUDING MIDRIB). CALCULATED TO A SAND-FREE AND WATER-FREE BASIS.

Grade Mark.	GRADE OF LEAVES.	Nicotine.	Resin and fatty substances.	Albuminoids.	Nitric acid.	Ammonia.	Cellulose.	Ash.
	1.—Cured by the Stalk Process.							
A	*Smokers*—Scrap from stalk	2 78	10.38	9.95	0	.134	10.19	12.72
C	Scrap	2.09	8.00	6.88	0	.124	10.91	13.34
D	Trash lug	2.07	7.56	5.65	0	.133	10.86	14.15
F	Best lug	2.05	7.44	6.55	0	.110	10.30	12.68
I	*Cutters*—Sand lug	2.32	8.21	6.52	0	.115	9.56	12.94
K	Best lug	2.64	7.46	6.29	0	.109	9.55	12.44
M	*Wrappers*—First grade	2.73	7.33	7.03	0	.129	9.42	11.99
N	Second grade	2.72	7.39	6.77	0	.123	9.40	11,70
P	*Fillers*—Bright tips	2.75	7.82	7.75	0	.140	9.28	10.10
S	Black tips	2.02	7.14	8.04	0	.119	9.39	10.70
W	Leaves for comparison	2.50	6.76	7.38	0	.111	8.59	11.48
	2.—Cured by the Leaf Process on Wire.							
B	*Smokers*—Scrap	2.30	6 34	7.16	0	.151	11.90	15.25
E	Trash lug	2.01	6.51	6.11	0	.125	10.79	15.19
G	Best trash lug	2.16	7.16	7.15	0	.143	10 07	13.52
H	*Cutters*—Sand lug	2.29	7.09	7.36	0	.136	9.92	12.79
J	Best lug	2.23	7.15	7.18	0	.133	9.53	13.14
L	*Wrappers*—First grade	2.44	6.90	6.69	0	.157	9.82	12.56
O	Second grade	2.83	6.91	9.05	0	.141	9.99	12.22
Q	*Fillers*—Bright tips	2 85	6.95	9.65	0	.151	9.62	10.63
R	Black tips	2.88	5.51	11.22	0	.179	9 38	11.77
X	Leaves for comparison	2.45	6.42	7.28	0	.130	8.60	11.09

The samples "X" and "W" represent fair samples of tobacco from the same plants, cured as follows: Thirty plants, which had an even number of leaves, were selected from the field, the alternate leaves stripped off from each plant, and strung on wire. The number of leaves on the wire was 129, and the same number were left on the stalk. Both the plants containing the remaining leaves and the leaves on the wires were then hung side by side in the Snow barn and cured with other tobacco. The samples by both processes were taken down, the leaves stripped from the stalk, and the leaves from both methods were weighed with these results:

Leaf-curing process	62½ oz.
Stalk-curing process	58½ oz.
Excess over stalk process	4 oz.

This experiment was suggested by the claim of the Snow Barn Co., that leaves cured by their process would weigh more than when cured on the stalk. It is true that the leaves cured on wire weighed a very little more in this case, but as there was so small a quantity of leaves tested, and only one trial, it is not safe to draw conclusions. The small variation might possibly have resulted from an excess of moisture only. The analysis of these samples shows no material difference in the composition, and as they represent samples of like growth, etc., the results are valuable in drawing conclusions in the principal experiment.

A complete consideration of the difference between the processes of curing, especially in reference to the chemical composition of the leaves as affected by the two methods, requires that we begin with the tobacco as it stood in the field before any of the harvesting had been done, for the reason that the manner and times of harvesting were quite different. By the stalk-curing process many of the lower leaves became ripe and dropped off before the plant was considered ripe enough to cut. When the plant was harvested some of the lower leaves were over-ripe, while the tips were still green.

By the leaf-curing process this difficulty was overcome to a certain extent. The leaves which would have been lost by the stalk process were saved by priming them off as they became ripe. The remaining leaves were primed in like manner until the whole plant, except the stalk, was harvested, which in this case was accomplished with three primings. The first priming by the leaf-cure took place August 17, the second September 1, and the third September 14. By the stalk-curing process all the tobacco was cut September 15, making nearly a month from the first priming by the leaf-curing process. Thus it will be seen that there was quite a difference in the time of harvesting by the two methods, which must necessarily have its effect upon the results.

By the leaf-curing process, the priming of the lower leaves has a tendency to renew the growth of the remaining leaves, which becomes very marked in case of the tip leaves. The analysis of these tip leaves shows a large increase in nitrogenous matter and nicotine compared with the stalk-cure. This would indicate a stronger and somewhat inferior quality of tobacco in case of these leaves, but the gain in weight more than compensates for the loss in quality. Aside from the tips there are no very marked variations in composition resulting from the two methods of curing. The slight difference noticed is probably due to the time and manner of harvesting to which reference has been made.

It will be noticed that the ash by the leaf-curing process is somewhat higher than by the stalk process. After the leaves of the tobacco plant, as with most other plants, arrive at a certain stage of growth, the tendency is for the percentage of ash to decrease if the plant is allowed to stand. As the difference in this case is most noticeable in the lower grades, representing the lower leaves, it is likely that this difference is largely due to the condition of the leaf when harvested. The same may be said of the organic nitrogenous substances, which are noticed to be slightly higher by the wire-curing process. This is particularly noticeable in case of the black tips, which in the wire-curing process have had the whole stalk to feed upon, developing a coarser and heavier leaf with a large increase of albuminoids

With reference to the resins and fatty substances, there seems to be a slight difference in favor of the stalk-cure. A noticeable feature in this connection is the large percentage of resins and fatty substances in sample A, representing the scrap from the stalk. This scrap consists of the extensions or wings of the leaf, which are attached to the stalks at the base of the leaf. It will also be seen that this sample is rich in nicotine and albuminoids. This sample cannot be considered in the comparison, as it was not saved by the wire-curing process.

The analysis of the different grades shows that a considerable variation is found in the leaves from different parts of the plant. Some of the variations found by comparing the two processes of curing can be accounted for from the fact that like grades by the different processes do not consist of leaves from the same portions of the plant.

The analyses of samples "X" and "W," with reference to the merits of curing the stalk with the leaf, and curing the leaf separate from the stalk, but having all the other conditions as nearly alike as possible, shows no material difference in the results. The more complete organic analyses of samples L and M (first grade wrappers) found in table VIII, including leaf, stem and stalk, are of interest as such, but with reference to this experiment there is nothing to change the observations already noted. One of the most remarkable features of this variety of tobacco is the large percentage of carbohydrates, especially that of glucose, which in this case reaches 17.54 per cent. of the whole leaf. This glucose in the stem by the leaf-curing process is considerably higher than by the stalk-process, while the reverse is true in case of the stalk. While it is true that glucose is the most liable to change of all the constituents of tobacco in the process of curing, it is believed that the differences are due in this case to the time and methods of harvesting.

TABLE VIII. ORGANIC ANALYSES OF TOBACCO DRIED AT 100° C. MORE COMPLETE THAN IN PRECEDING TABLES.

Station number.	Grade mark.	DESCRIPTION.	Nicotine.	Resin and fatty substances.	Starch.	Glucose.	Albuminoids (N×6.25).	Pectic acid (anhydride).	Citric acid (anhydride).	Malic acid (anhydride).	Oxalic acid (anhydride).	Acetic acid (anhydride).	Nitric acid (anhydride).	Ammonia.	Cellulose (crude fiber).	Sand.	Ash.	Undetermined.	Total.
1.—Cured by the Stalk Process.																			
13	M	Leaf	3.23	8.31	6.35	19.05	7.56	5.63	1.22	8.21	1.23	.44	.00	.131	7.05	.56	10.54	20.49	100
34	M	Stem	.72	3.31	5.86	11.65	4.81	10.49	.33	5.23	2.04	.19	.00	.113	18.49	.21	17.37	19 19	100
	M	Whole leaf, First Grade Wrapper	2.72	7.29	6.25	17.54	7.00	6.62	1.04	7.59	1.62	.39	.00	.127	9.38	.49	11.93	20.03	100
43		Stalk	.77	.96	11.42	10.50	7.99	3.83	.29	1.05	1.28	.19	.00	1.18	29.29	.18	8.73	22.39	100
2.—Cured by the Leaf Process on wire.																			
12	L	Leaf	2.84	7.94	5.13	18.08	6.94	4.72	.95	7.64	1.39	.48	.00	.161	7.03	3.62	10.66	22.42	100
33	L	Stem	.49	1.72	5.70	14.56	4.69	10.04	.27	4.32	1.71	.24	.00	.119	19.43	.75	18.27	17.69	100
	L	Whole leaf, First Grade Wrapper	2.37	6.69	5.24	17.37	6.49	5.79	.81	6.97	1.45	.43	.00	.153	9.52	3.05	12.18	21.49	100
44		Stalk	.77	.82	11.56	7.41	7.19	3.97	.26	1.30	1.47	.11	.00	.99	31.10	.32	9.29	23.44	100

ASH ANALYSES.

For further comparison, the following complete ash analyses (table IX), were made of samples L and M (first grade wrappers), including the leaf, stem and stalk. The large percentage of insoluble silica in No. 12 indicates that many of the lower leaves, having a large percentage of sand adhering, were used as wrappers by the Snow process, which were either lost or unsuitable for this grade in the stalk process.

TABLE IX. ASH ANALYSES OF TOBACCO.

Station Number.	Grade Mark.	Part of tobacco analyzed.	Total Ash.	Total ash exclusive of sand, carbon and carbonic anhydride.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosphoric acid.	Sulphuric acid.	Chlorine.	Carbonic acid.	Soluble silica.	Insoluble silica.	Carbon.	Minus oxygen equivalent of chlorine.	Total.
12	L	Leaf	14.28	8.51	13.48	.35	25.76	5.39	.33	1.87	3.36	4.20	4.50	14.49	1.29	25.34	.59	1.02	99.93
13	M	Leaf	11.10	8.09	20.32	.94	30.08	5.80	.50	1.18	3.88	6.08	4.56	21.76	.89	5.08	.30	1.03	100.34
33	L	Stem	19.02	15,38	27.16	.91	23.68	7.47	.65	.91	4.00	3.96	15.85	14.48	.84	4.00	67	3.59	100.99
34	M	Stem	17.58	14.30	27.64	.87	23.88	7.74	2.05	.47	4.22	4.20	13.42	17.05	.68	1.18	.47	3.04	100.83
43		Stalk	8.91	7.49	27.08	.82	23.92	7.16	.33	.79	5.96	7.29	11.78	13.79	.97	1.92	.25	2.66	99.40
44		Stalk	9.61	7.94	28.08	.79	21.96	7.06	.65	.91	4.96	7.90	11.85	13.90	.92	3.28	.21	2.68	99.79
	L	Whole leaf	15.23	9.89	16.23	.46	25.34	5.81	.39	1.68	3.48	4.15	6.78	14.48	1.20	21.05	60	1.54	100.14
	M	Whole leaf	12.42	9.35	21.81	.93	28.71	6.19	.82	1.03	3.95	5.70	6.37	20.80	.85	4 28	33	1.44	100.33

Table X represents the preceding table calculated on a different basis, and consists of the proportion of mineral ingredients contained in 100 parts of the ash exclusive of sand, carbonic acid, and carbon.

Table XI shows the proportion of mineral ingredients and nitrogen content in 100 parts of the tobacco dried at 100° C. While in general there are no large differences in the percentage of ash constituents by the leaf and stalk cures, there are some quite marked variations.

The percentage of potash in the whole leaf by the leaf-cure is several per cent. less than by the stalk-cure, while the reverse is true in the case of chlorine. It is known that the amount and composition of the ash is constantly changing during the growth of the tobacco plant. There is, also, a marked variation in the leaves of different portions of the plant. It is probable, therefore, that the variations may be due to these causes.

The first priming for the leaf-cure took place about a month previous to the cutting for the stalk-cure, and many of the leaves from the first and second priming were classed with the best grades, but were lost or damaged in the stalk-cure. The priming of the lower leaves also changes the character of those remaining to a certain extent by causing an increased growth.

TABLE X. PERCENTAGE COMPOSITION OF ASH OF TOBACCO, EXCLUSIVE OF SAND, CARBONIC ACID, AND CARBON.

Station No.	Grade mark.	DESCRIPTION OF SAMPLE.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosphoric Acid.	Sulphuric Acid.	Chlorine.	Silica.	Minus oxygen equiv. of Cl.	Total.
12	L	Leaf—Leaf-cure	22.66	.59	43.29	9.06	.55	3.14	5.64	7.06	7.56	2.17	1.72	100
13	M	Leaf—Stalk-cure	27.75	1.29	41.09	7.92	.69	1.61	5.31	8.30	6.23	1.22	1.41	100
33	L	Stem—Leaf-cure	33.19	1.11	28.94	9.13	.79	1.11	4.89	4.84	19.38	1.02	4.39	100
34	M	Stem—Stalk-cure	33.65	1.06	29.07	9.42	2.49	.58	5.14	5.12	16.34	.83	3.70	100
43		Stalk—Stalk-cure	32.46	.99	28.67	8.58	.39	.95	7.14	8.73	14.12	1.16	3.19	100
44		Stalk—Leaf-cure	34.05	.96	26.63	8.56	.79	1.10	6.01	9.58	14.37	1.11	3.24	100
	L	Whole leaf—Leaf-cure	25.37	.72	39.60	9.08	.61	2.63	5.44	6.49	10.59	1.88	2.41	100
	M	Whole leaf—Stalk-cure	29.10	1.24	38.32	8.27	1.09	1.38	5.27	7.60	8.51	1.14	1.92	100

TABLE XI. PROPORTION OF MINERAL INGREDIENTS AND TOTAL NITROGEN IN 100 PARTS OF TOBACCO, DRIED AT 100° C.

Station No,	Grade mark.	DESCRIPTION OF SAMPLE.	Potash,	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Phosph'c acid.	Sulph'ric acid	Chlorine.	Silica.	Minus oxygen equiv. of chlo- rine.	Tot. mineral ingredients.	Tot. nitrogen.
12	L	Leaf—Leaf-cure	1.93	.05	3.68	.77	.05	.27	.48	.60	.65	.18	.15	8.51	1.79
13	M	Leaf—Stalk-cure	2.24	.10	3.32	.65	.06	.13	.43	.67	.50	.10	.11	8.09	1.88
33	L	Stem—Leaf-cure	5.11	.17	4.45	1.40	.12	.17	.75	.74	2.98	.16	.67	15.38	.95
34	M	Stem—Stalk-cure	4.81	.15	4.16	1.35	.36	.08	.74	.73	2.33	.12	.53	14.30	.98
43		Stalk—Stalk-cure	2.43	.07	2.15	.64	.03	.08	.53	.65	1.06	.09	.24	7.49	1.54
44		Stalk—Leaf-cure	2.71	.08	2.11	.68	.06	.09	.48	.76	1.14	.09	.26	7.94	1.37
	L	Whole leaf—Leaf-cure	2.50	.07	3.92	.90	.06	.26	.54	.64	1.05	.19	.24	9.89	1.62
	M,	Whole leaf—Stalk-cure	2.72	.12	3.58	.77	.10	.13	.49	.71	.80	.11	.18	9.35	1.70

ANALYSES OF AMERICAN TOBACCOS.

The following analyses (tables XII and XIII), taken from very complete report* on The Production of Tobacco in the United States, in the Tenth Census, represent the composition of the principal varieties of tobacco grown in different portions of the United States, analyzed by Dr. G. E. Moore. They are inserted to lend additional interest to the previous tables of analyses.

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*Tenth Census. "Statistics of Agriculture," p. 269.

TABLE XII. PERCENTAGE COMPOSITION OF TOBACCOS, DRIED AT 100° C.

Number of sample.	VARIETY.	Nicotine.	Resin and fatty substances.	Starch.	Glucose.	Albuminoids (N×6.25).	Pectic acid (anhydride).	Citric acid (anhydride).	Malic acid (anhydride).	Oxalic acid (anhydride).	Acetic acid (anhydride).	Nitric acid (anhydride).	Ammonia.	Cellulose (crude fiber).	Sand.	Ash, exclusive of sand and carbonic acid.	Undetermined.	Total.
3	Virginia; sun-cured; for manufacturing plug tobacco.	3.26	4.15	5.89	6.89	16.09	6.19	2.12	5.02	0.84	0.42	0.00	0.33	9.58	0.55	12.41	26.26	100
5	Virginia; fire-cured; for German and continental trade; low grade.	4.30	4 65	2.75	2.75	13.66	7.46	2.84	7.58	1.03	0.55	0.00	0.32	9.24	2.38	13.36	27.13	100
7	Tennessee, Clarksville; fire-cured; gummy; for German and English markets; soil: heavy, rich loam.	5.29	4.99	3.54	0.00	16.54	6.01	2.99	5.51	1.30	0.39	1.55	0.98	9.68	2.25	14.37	24.61	100
19	Kentucky, Mason Co.; air-cured; for cutting or plug tobacco.	3.12	5.34	4.45	0.00	15.98	7.49	4.05	9.26	2.18	0.64	0.00	0.48	12.18	0.66	16.06	18.11	100
10	North Carolina, Granville Co.; bright wrapper; grown on white or light gray sand.	2.70	5.73	6.71	16.39	8.75	5.97	0.43	7.41	0.46	0.53	0.00	0.19	9.13	1.26	8.49	25.85	100
28	Louisiana "Perique" tobacco; "cured in its juices."	4.32	6.28	2.45	0.00	15.80	6.66	1.18	3.94	3.49	1.62	0.00	0.76	9.08	4.17	13.30	26.95	100
37	Louisiana "Perique" tobacco; air-cured.	4.25	7.26	2.79	0.00	16.50	7.43	4 31	7.90	2.06	0.28	1.65	1.65	8.30	0.76	15.54	19.32	100
35	Connecticut seed-leaf, New Milford; soil: rich loam.	4.06	4.29	3.22	0.00	18.09	6.29	5.80	10.09	0.92	0.31	3.23	0.65	10.61	1.34	15.10	16.00	100
30	Connecticut seed-leaf, Hartford; sandy soil.	1.14	2.93	3.14	0.00	17.33	11.24	4.95	5.04	0.95	0.48	2.39	0.62	15.23	1.48	18.56	14.52	100
34	Penn. seed-leaf; Lancaster Co.,	1.04	4.02	3.67	0.00	14.62	12.59	1.61	5.46	0.94	0.57	0.00	0.22	15.12	1.64	17.98	20.52	100
16	Ohio seed-leaf ------------------	1.92	3.87	3.19	0.00	15.30	7.46	3.46	6.58	1.42	0.42	3.41	0.92	12.87	1.85	14.22	23.11	100
22	New York State seed-leaf--- ---	2.35	3.02	2.63	0.00	16.26	9.89	4.42	8.27	1.11	0.41	2.29	1.20	12.15	1.94	15.50	18.56	100
25	Wisconsin and Illinois seed-leaf--	0.86	3.28	4.15	0.00	20.34	11.61	2 99	6.88	1.07	0.68	1.22	0.63	12.97	1.53	15.43	16.36	100

TABLE XIII. ASH ANALYSES.

Number of sample.	VARIETY.	Total ash.	Ash, exclusive of sand and carbonic anhydride.	Potash.	Soda.	Lime.	Magnesia.	Ferric oxide.	Alumina.	Manganous oxide.	Phosphoric anhydride.	Sulphuric anhydride.	Silicic anhydride.	Chlorine.
3	Virginia; sun-cured; for manufacturing plug tobacco.	14.29	12.41	34.16	0.26	31.76	7.91	0.58	1.22	0.00	3.81	4.99	1.39	13.92
5	Virginia; fire-cured; for the German and continental trade; low grade.	17.42	13.36	26.55	0.22	36.96	11.51	0.95	1.81	0.00	3.23	4.27	3.29	11.21
7	Tennessee, Clarksville; fire-cured; gummy; for the German and English markets; soil: heavy, rich loam.	19.23	14.37	33.15	0.15	36.48	11.85	0.51	0.95	0.25	4.42	6.16	3.42	2.66
19	Kentucky, Mason county; air-cured; for cutting or plug tobacco.	21.85	16.06	39.51	0.86	39.80	5.34	1.56	0.51	0.13	6.09	4.52	1.20	0.48
10	North Carolina, Granville county; bright wrapper; grown on white or light gray sand.	11.19	8.49	41.56	0.47	28.12	9.78	0.59	0.29	0.11	5.23	4.53	2.75	6.57
37	Louisiana "Perique" tobacco; air-cured (leaf deprived of midrib).	19.82	15.54	30.23	0.25	37.47	12.43	1.19	0.72	0.29	6.18	6.19	1.91	3.14
35	Connecticut seed-leaf, New Milford; soil: rich loam.	21.08	16.30	35.08	0.01	40.38	11.33	1.47	0.74	0.13	3.20	4.08	1.39	2.19
30	Connecticut seed-leaf, Hartford; sandy soil....	22.92	18.56	41.30	0.26	28.70	7.56	2.13	0.83	0.00	3.26	3.34	1.09	11.58
34	Pennsylvania seed-leaf; Lancaster county.....	24.74	17.98	49.60	0.36	28.55	8.18	1.39	1.05	0.00	5.72	2.61	1.05	1.49
16	Ohio seed-leaf..................................	19.95	14.22	33.37	0.27	34.69	17.32	1.07	0.93	trace	4.29	3.48	3.07	1.51
22	New York State seed-leaf....................	21.12	15.50	33.13	0.39	39.26	8.60	0.74	0.56	0.16	3.61	3.78	3.67	6.10
25	Wisconsin and Illinois seed-leaf..............	20.81	15.43	38.71	1.08	33.49	12.57	0.79	0.74	trace	3.09	3.89	4.65	0.99

CONCLUSIONS.

1. In arriving at conclusions in this experiment it is necessary to distinguish between the immediate effects of the curing and the effect that the priming, time of harvesting, etc., have had on the quantity and quality of tobacco produced. On account of the great diversity in the character and composition of different vareties of tobacco, together with the various methods employed in curing, these conclusions can only apply to yellow tobacco and varieties similar to it, when cured according to the methods employed in this experiment.

2. The larger amount of tobacco obtained by the leaf-curing process resulted both from saving all the lower leaves when at their best, and an increased growth of the upper part of the plant, caused by priming the lower leaves.

3. The superior quality and appearance of the bulk of the tobacco cured by the leaf-process as indicated by the sale, was mainly due to the fact that the leaves were harvested as they became mature. By the stalk process many of the lower leaves were over-ripe, while the tips were still green. In addition, it is believed that the leaves received less damage from handling by the leaf-curing process than when handled on the stalk.

4. The difference in chemical composition of like grades resulting from the two methods of curing is chiefly due to the manner and time of harvesting. This difference is most noticeable in case of the fillers, where the increased growth, caused by priming the lower leaves in the leaf-curing process, has made a large increase in the percentage of albuminoids and nicotine. Some of the differences are also due to the variation in composition of leaves from different parts of the stalk selected to make up these grades.

5. The chemical composition of tobacco cured by similar methods is not materially affected by separating the leaf from the stalk before curing, provided the condition of the tobacco is the same when put in the barn.

6. The time required for curing leaves from different parts of the plant varies according to their ripeness. Some of these leaves require an entirely different range of temperature from others to produce the required color, etc. For these reasons the leaf-curing process is more desirable, as the barn is filled each time with tobacco requiring like treatment to produce the best results in color, quality and general appearance.

7. The priming process as followed in the leaf-cure method has a marked effect on the growth and chemical composition of the leaves taken from the upper part of the plant. The removal of the lower leaves causes the top of the plant to grow with increased vigor, thus producing heavier and coarser leaves, with a considerable increase

in the percentage of organic nitrogenous matter and nicotine. While the quality is somewhat injured by this transformation, it appears that the gain in weight more than compensates for the loss in quality.

8. The slightly larger percentage of resins and fatty substances resulting from the stalk process, as compared with the leaf process, is not worthy of especial notice, on account of the smallness, and probably results from the deficiency of the other constituents.

9. The excess of sand found in the best grade wrappers from the leaf-curing process indicates that a portion of the lower leaves were classed as wrappers which were not available as such by the stalk process.

10. The presence of a large percentage of carbohydrates, especially starch and glucose, is characteristic of the yellow tobacco grown on the light, sandy soil of Granville county. This soil, although containing a remarkably small percentage of available mineral matter, seems to be peculiarly adapted to the development of these organic compounds. The character of soil may also cause the low percentage of ash, as compared with other varieties.

11. The higher ash percentage by the leaf-curing process is due to the time and manner of harvesting rather than the method of curing. The analyses of the ash of the best grade wrappers from both processes show some variations in chemical composition, which are evidently due to the conditions of growth, etc., affecting the tobacco before the curing was commenced.

12. The complete organic and inorganic analyses of stalk, stem, and leaf, as tabulated in preceding tables, are of interest, as showing the relative percentage of the various constituents found in the different parts of the plant.

13. The carefully regulated drying by artificial heat, as practiced in the Snow barn and the old-style log-barn, reduces the fermentative changes, which take place in the process of curing, to a minimum. Of all the organic compounds, glucose is especially liable to change in the process of curing, but in this case it is believed that practically the whole amount which was present in the green leaf remains unchanged in the dried product.

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CHEMICAL ANALYSES

OF

SOME NATIVE NORTH CAROLINA GRASSES, FORAGE PLANTS, GRAINS, SEEDS, AND BY-PRODUCTS.

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CHEMICAL ANALYSES

OF

SOME NATIVE NORTH CAROLINA GRASSES, FORAGE PLATNS, GRAINS, SEEDS, AND BY-PRODUCTS.

By B. W. KILGORE, Assistant Chemist.

The present bulletin contains the result of recent chemical analyses at this Station of some native North Carolina grasses not heretofore analyzed, as well as some food materials and by-products.¶

The analyses are presented on the basis of air-dry hay, and as they would ordinarily be fed, as well as on the basis of dry matter, or water-free substance. The latter is the better basis, at least for comparing the composition of the different grasses, inasmuch as the water in the air-dry hay varies greatly under different conditions.

I. SOME NATIVE NORTH CAROLINA GRASSES.

In Table I is presented the analyses of wild grasses made at the Station during the past two or three years, and it is hoped they will prove of interest by contributing to our knowledge of their values as foods. Those marked (*) were collected by the Botanist of the Station, Mr. Gerald McCarthy, around Wilmington, N. C., in September, 1890. The marsh-grass hay (the last in the table) was sent by Messrs. Cronly & Morris, of Wilmington, for analysis, with the claim that the process of preparation which it had undergone had greatly enhanced its value as a hay. All the others were obtained from the different county exhibits (mainly Warren, Buncombe, Forsyth, and Ashe) at the Southern-Interstate Exposition at Raleigh, in October and November, 1891.

The composition and value of grasses as cattle foods vary, with the stage of growth. It is to be regretted that most of the samples presented here were *ripe* or *nearly ripe*, which is beyond the stage for making the best hay; and, in addition, the Exposition samples had been somewhat damaged in being exposed to the dust for two months. The stage of growth, as far as could be, has been represented in the table, and allowances can be made for the advanced stage of maturity, and a better hay be expected if cut at the proper haying stage. Even those that were not collected at the best time are of value in giving an idea of what to expect of them when they are so harvested. Taking them as they are here, those specially promising, judging from composition (but this must not be followed blindly), are marked (†) in the table, while those comparing fairly well with the average timothy, red top, and orchard grass are designated with (‡).

¶The analyses were made by Messrs. Kilgore, Carpenter, Meng, and Noble.

TABLE I. SHOWING THE PERCENTAGE COMPOSITION OF SOME OF THE WILD GRASSES OF NORTH CAROLINA.

NAME OF GRASS.	Station laboratory number.	Parts in 100 of Air-dry Substance.							Parts in 100 Water-free Substance.					
		Water.	Total protein (N.×6.25).	Fats (ether extract).	Nitrogen-free ex't.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N.×6.25).	Fats (ether extract).	Nitrogen-free ex't.	Crude fiber.	Ash.	Total nitrogen.
Yellow pigeon grass (Setaria glauca), nearly ripe	199	3.20	5.00	3.80	47.48	31.77	8.75	.80	5.16	3.93	49.05	32.82	9.04	.82
Gama grass (Tripsacum dactyloides), nearly ripe	200	13.48	4.69	1.69	35.90	37.67	6.57	.75	5.42	1.96	41.49	43.53	7.60	.86
Gama grass (Tripsacum dactyloides)†*	174	7.63	8.22	1.74	45.07	30.73	6.61	1.46	9.88	1.88	47.81	33.27	7.16	1.58
Rhode Island bent grass (Agrostis canina), over ripe‡	201	7.12	6.06	1.93	46.28	31.92	6.69	.97	6.52	2.07	49.85	34.36	7.20	1.64
Knee grass (Panicum proliferum), in flower†	206	8.73	13.50	3.26	41.51	25.32	7.68	2.16	14.79	3.57	45.49	27.74	8.41	2.36
Broad-leafed panic grass (Panicum latifolium), nearly ripe	212	4.38	5.00	1.88	41.41	43.50	3.83	.80	5.23	1.97	43.31	45.49	4.00	.83
Two-edged panic grass (Panicum anceps), nearly ripe‡	211	4.28	5.94	1.55	46.03	35.37	6.83	.95	6.21	1.62	48.09	36.95	7.13	.99
Creeping panic grass (Panicum dichotomun), nearly ripe‡.	213	10.32	7.00	1.55	42.61	33.42	5.10	1.12	7.81	1.73	47.50	37,27	5.69	1.25
Wild panicum (Panicum verrucosum), nearly ripe†	205	5.74	8.56	2.60	44.85	31.05	7.20	1.37	9.08	2.75	47.59	32.94	7.64	1.45
Panicum microcarpon, ripe‡	204	9.81	7.31	2.58	44.75	28.85	6.70	1.17	8.10	2.86	49.64	31,98	7.42	1.29
Barnyard grass (Panicum crusgalli), ripe, and seed badly shattered*	176	7.74	4.50	1.06	46.34	33.32	8.04	.72	4.88	1.15	49.13	36.12	8.71	.78
False red top (Panicum agrostoides), nearly ripe‡*	180	8.46	7.50	1.57	38.18	33.13	11.16	1.20	8.19	1.71	41.72	36.19	12.19	1.31
Switch grass (Panicum virgatum), ripe‡*	181	8.02	7.44	1.48	43.95	33.45	5.66	1.19	8.09	1.61	47.78	36.37	6.15	1.27
Bitter grass (Panicum amarum), nearly ripe†*	177	7.52	10.37	1.95	41.83	29.66	8.67	1.66	11.22	2.11	45.23	32.07	9.37	1.77
American canary grass (Phalaris arundinacea)*	175	5.11	3.54	2.19	52.11	31.68	5.37	.57	3.75	2.31	54.89	33.39	5.66	.60
Awned bunch grass (Aristida purpurea)*	178	7.95	3.94	1.08	46.73	36.26	4.04	.63	4.28	1.17	50.77	39.39	4.39	.68
Sea grass (Uniola paniculata)*	179	1.78	4.70	4.13	54.18	30.51	4.70	.77	4.89	4.20	55.06	31.06	4.79	.75
Broad-leafed false fescue (Uniola latifolia), half ripe†	216	6.75	9.06	2.72	39.01	34.50	7.96	1.45	9.71	2.91	41.85	37.00	8.53	1.55
Wild rice grass (Zizania aquatica), ripe*	182	7.29	1.75	1.41	44.43	33.63	11.49	.28	1.89	1.52	47.93	36.27	12.39	.30
Swamp cane (Arundinaria macrosperma)†*	183	8.53	11.31	4.10	30.66	35.00	10.40	1.81	12.36	4.48	33.53	38.26	11.37	1.98
Cord grass (Spartina juncea)*	184	7.47	3.62	2.15	54.28	27.53	4.95	.58	3.91	2.32	58.67	29.75	5.35	.62
Marsh cord grass (Spartina polystachy var. glabra), just out of flower	221	10.02	3.94	1.30	45.96	35.45	3.33	.63	4.38	1.44	51.08	39.40	3.70	.69
Horned sedge (Rhyncospora corniculata), ripe, and seed badly shattered*	185	8.81	4.75	2.07	39.80	34.80	9.77	.76	5.21	2.27	43.64	38.16	10.72	.83
Horned sedge (Rhyncospora corniculata)‡	220	5.85	6.37	2.95	48.38	31.92	4.53	1.02	6.76	3.13	51.40	33.90	4.81	1.08
Twisted beard grass (Erianthus contortus)*	186	8.47	4.13	4.75	39.75	40.27	2.63	.66	4.51	5.19	43.43	44.00	2.87	.72

TABLE I.—CONTINUED.

NAME OF GRASS.	Station laboratory number.	Parts in 100 of Air-dry Substance.							Parts in 100 Water-free Substance.					
		Water.	Total protein (N.×6.25).	Fats (ether extract).	Nitrogen-free ex't.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N.×6.25).	Fats (ether extract).	Nitrogen-free ex't).	Crude fiber.	Ash.	Total nitrogen.
Beard grass (Erianthus alopecurus), over-ripe	227	5.15	4.06	1.85	53.74	32.00	3.20	.65	4.28	1.95	56.66	33.74	3.37	.68
Pickerel weed (Pontederia cordata)†*	187	10.55	14.06	2.83	35.23	24.00	12.53	2.25	15.72	3.16	39.38	27.73	14.01	2.51
Sedge (Cyperus flavescens)‡*	188	8.08	5.56	6.08	38.00	25.50	16.78	.89	6.05	6.61	41.33	27.74	18.26	.97
False red top (Triodia seslerioides), just out of flower‡	208	8.50	6.56	1.60	33.22	41.35	8.77	1.05	7.17	1.74	36.32	45.19	9.58	1.14
False rice (Leersia Virginica), just out of flower†	217	5.02	8.75	2.45	41.48	31.65	10.65	1.40	9.21	2.58	43.67	33.33	11.21	1.47
Broom sedge (Andropogon Virginicus), ripe	218	3.75	4.37	1.89	39.86	41.40	8.73	.70	4.54	1.96	41.42	43.01	9.07	.72
Yard goose grass (Elusine Ægyptiacum), in flower†	222	5.01	12.75	2.20	35.74	33.75	10.55	2.04	13.42	2.31	37.63	35.53	11.11	2.14
Bull grass (Paspalum purpurascens)‡	323	10.90	6.25	2.63	40.89	32.73	6.60	1.00	7.01	2.95	45.89	36.73	7.42	1.12
Marsh grass hay‡ (Spartina sp.)	324	13.50	6.00	2.80	32.08	34.32	11.30	.96	6.93	3.23	37.08	39.67	13.09	1.10

*Samples collected by Gerald McCarthy, Botanist of the Station.

†Specially promising.

‡Promise well as forage plants.

II. SOME FORAGE PLANTS, GRAINS, SEEDS, AND BY-PRODUCTS.

Table II gives the results of recent chemical analyses at this Station of various food materials and by-products. These analyses include

1. Some Cultivated Grasses.—These are a few of our common cultivated grasses recently analyzed at the Station, the samples being grown on Capt. B. P. Williamson's farm and the Experiment farm.

2. Non-Saccharine and Saccharine Sorghums and Millets.—Analyses of the whole plant and parts of plants of some of the non-saccharine, or non-sugar producing sorghums, two of the sugar yielding sorghums, and some millets. They are especially rich in nitrogen-free extract, and most of them make a good showing in protein and fats for plants of these classes. The kaffir corn and millo maize were sent to the Station by Mr. Jasper Stowe, Belmont, N. C. The other samples were grown on the Experiment farm.

3. Corn Plant and its Parts, Wheat Bran, and Oat Meal.—Uuder this is shown the composition of the whole corn plant, parts of the plant, the grain, and meal made from it, and corn silage, together with oat meal, and wheat bran. The corn plant and its parts are high in carbohydrates, and the pulled fodder, or corn leaves, whole grains, and corn meal also contain a good percentage of protein and fats. Oat meal and wheat bran are more nitrogenous foods than the corn plant or any of its parts, and are very valuable and nutritious foods. Their comparative composition can be seen from the table.

4. Leguminous Plants.—The composition of leguminous plants is shown. They will be noticed to be especially rich in protein or the "flesh formers," containing a far larger proportion of these bodies than do any of the preceding classes of plants Those in this class making the best showing in this respect are soja bean, crimson clover, lucerne, and cowpea-vines. As the protein compounds are estimated by the nitrogen content of plants, columns for total nitrogen in original and water-free substances have been inserted in this and the other tables of compositions that comparisons of different plants and classes of plants may be made in their content of this element. It is now well established that the clovers, cowpea, peanut, and other leguminous or pod-bearing plants have the power of utilizing the free nitrogen of the atmosphere in the growth and building up of their structures. Most of these plants, it will be seen, contain as much, and some of them more, nitrogen than a great many of the commercial fertilizers applied to the land to increase plant growth, and inasmuch as nitrogen is nearly three times the costliest element of these fertilizers and a constituent of the most costly and valuable compounds (protein bodies) in plants for animal production, connected with the fact that the other classes of agricultural plants do not possess as do the leguminous ones this power of appropriating the *free nitrogen* of the air in their growth, points to leguminous plants as deserving of new and more important relations to agricultural economy. The free nitrogen used by them is a clear gain; it is used in the formation of protein compounds, which, whether fed to animals for nutrition and afterwards returned, in part, in the manure to the soil, or turned under or allowed to decay on the soil where it grew, is capable of being utilized by other plants for making their growth. The unusually large amount of fats in the soja bean is also worthy of special consideration.

5. *Peanut Plant: Vines, Nuts, Kernels, and Hulls.*—Here is shown the chemical composition of peanut-vines, kernels, and the hulls of the kernels. The peanut is a leguminous plant, and like the rest of this family uses the nitrogen of the air in its growth. The composition of the vines or tops indicate them to be a good cattle food, and, in fact, they are used quite largely in this State for feed. A digestion experiment will soon be made with them to ascertain their feeding value. The kernels are high in their content of both protein and fats. The oil of the peanut kernel is clear, light colored with a slightly yellowish tint. The proportion of hulls to kernels in the separation made for the analyses were: hulls, 28.8 per cent.; kernels, 71.2 per cent. The kernels show a very large percentage of oil, which combined with the high proportion of weight as compared with the hulls, would show the peanut to be a valuable oil-producing plant. Taking 22 pounds as a bushel of peanuts (whole fruit) and 35.01 as the percentage of oil in them, one bushel would contain 7.7 pounds of oil, considerably more than a bushel of cotton-seed.

6. *Cotton-seed and Products and Cotton Stalks.*—It is seen that raw and roasted cotton-seed, on the water-free substance, differ but little in composition, and it would seem that the seed have not been changed in composition by roasting so far as the ordinary fodder analysis will show.

The raw and roasted seed analyzed were portions of the same lot. Meal from roasted cotton-seed is the kernel separated from the hulls after roasting. It runs high in both protein and fats. The cotton stalks were taken from the field just after the cotton was picked, and include the burrs and what few leaves were remaining at that time. Their feeding value as indicated by analysis is worthy of note. Cotton-seed hulls and meal are too common to require explanation. The meal will be observed to be an extremely nutritious food. The market value of cotton-seed has increased very rapidly of late years During a portion of last season they sold in this market for 33 cents per bushel. This is due in part to the extended use of cotton-seed oil. One bushel, weighing 30 pounds and containing 19.38 per cent. of oil, contains 5.8 pounds of oil.

TABLE II. ANALYSES OF NORTH CAROLINA FORAGE PLANTS, GRAINS, SEEDS, AND BY-PRODUCTS.

	Laboratory number.	Parts in 100 of fresh or air-dry substance.							Parts of 100 in water-free substance.					
		Water.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N.×6.25).	Fats (ether extract.)	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.
1. SOME CULTIVATED GRASSES.														
Italian rye grass (Lolium Italicum)	161	10.00	13.50	3.08	30.36	29.58	13.48	2.16	15.00	3.42	33.73	32.86	14.97	2.40
Fowl meadow grass	163	10.12	8.69	2.30	44.42	27.93	6.54	1.39	9.66	2.55	49.42	31.07	7.27	1.54
Johnson grass (Sorghum halapense)	162	10.50	7.44	2.28	40.49	31.09	8.20	1.19	8.31	2.54	45.25	34.74	9.16	1.32
Orchard grass (Dactylis glomerata) n'ly ripe	209	5.25	6.69	2.60	41.13	38.43	5.90	1.07	7.06	2.74	43.41	40.56	6.23	1.12
Orchard grass[1]		15.35	8.12	3.53	35.73	31.14	6.13	1.29	9.59	4.17	42.20	36.79	7.24	1.52
2. NON SACCHARINE AND SACCHARINE SORGHUMS AND MILLETS														
Kaffir corn—whole plant	146	10.94	3.31	2.50	47.40	30.37	5.48	.53	3.71	2.81	53.23	34.10	6.15	.59
Kaffir corn—mature head	147	16.23	6.92	2.86	65.16	6.79	2.02	1.11	8.26	3.41	77.80	8.12	2.41	1.32
Kaffir corn flour	148	16.75	6.62	3 82	69.47	1.16	2.18	1.06	7.95	4.58	83.44	1.39	2.64	1.27
Kaffir corn middlings	149	16 72	8.62	2.68	69.43	1.09	1.46	1.38	10.35	3.21	83.37	1.32	1.75	1.65
White millo-maize—mature head	150	15.66	8 18	2.81	63 15	8.45	1.75	1.31	9.69	3.33	74.89	10.02	2.07	1.55
Yellow millo-maize—mature head	151	15.66	7.62	2.79	62.78	8.47	2.68	1.22	9.03	3.30	74.45	10.04	3.18	1.45
Dhoura corn	144	10.26	4.44	1.76	44.41	33.41	5.72	.71	4.94	1.96	49.50	37.23	6.37	.79
Broom corn	152	9.41	3.87	1.85	42.37	36.76	5.74	.62	4.27	2.04	46.79	40.57	6.33	.68
Sorghum, early orange	153	10.02	3.69	5.47	49 64	27.76	3.42	.59	4.10	6.08	55.17	30.85	3.80	.66
Sorghum, early amber	154	10.49	5.20	4.27	45.19	30.68	4.17	.83	5.80	4.77	50.51	34.27	4.65	.94
German millet	155	10.82	6.75	1.83	47.61	26.60	6.39	1.08	7.57	2.05	53.38	29.82	7.18	1.21
Pearl millet	156	9.90	8.31	1.66	33.04	34.74	12.35	1.31	9 22	1.84	36.67	38.57	13.70	1.45
Pearl millet, headed	157	9.27	7.15	1.60	38.01	35.42	8.55	1.14	7.88	1.76	41.92	39.03	9.42	1.25
Hungarian millet	158	9.92	10.62	2.71	45.60	22.38	8.77	1.70	11.78	3.01	50.64	24.84	9.73	1.88

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[1] Analysis by New York State Experiment Station, Eighth Annual Report.

TABLE II.—CONTINUED.

	Laboratory number.	Parts in 100 of fresh or air-dry substance.							Parts of 100 in water-free substance.					
		Water.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.
3. CORN PLANT AND ITS PARTS; OAT MEAL AND WHEAT BRAN.														
Ensilage corn—stalks, ears and leaves	170	73.89	2.11	.52	16.95	5.38	1.15	.34	8.09	1.99	64.92	20.61	4.39	1.29
Corn stalks	173	67.65	1.56	.62	16 84	11.61	1.73	.25	4.81	1.91	52.06	35.88	5.34	.77
Corn leaves—fodder, as pulled	171	27.11	10.04	1.48	38.80	16.66	5.92	1.60	13.77	2.03	53.23	22.85	8.12	2.20
Corn leaves—air-dry	253	10.72	9 61	3.96	45.65	22.85	7.21	1.54	10.76	4.43	51.13	25.60	8.08	1.72
Corn silage—whole plant[2]		71.98	2.11	0.61	16.42	7.72	1.16	.34	7.53	2.53	58.25	27.54	4.15	1.20
Corn meal	168	12.47	7.37	3.35	72.81	2.44	1.56	1.18	8.42	3.83	83.16	2.79	1.78	1.34
Hominy mill feed	139	6.92	10.06	8.68	66.65	3.92	3.77	1.61	10.80	9.32	71.60	4.21	4.05	1.71
Whole corn—grain[3]		10.52	10.59	5.44	69.81	2.09	1.55	1.69	11.82	6.07	78.01	2.33	1.73	1.88
Oat meal	167	10.48	12.37	4 80	57.93	10.31	4.11	1.98	13.83	5.36	64.71	11.51	4.59	2.21
Wheat bran	166	11.35	14.50	3.27	54.62	9.68	6.58	2.32	16.36	3.69	61.61	10.92	7.42	2.61
4. LEGUMINOUS PLANTS.														
Lucerne (Medicago sativa)	160	12.42	15.25	2.18	33.77	29.42	6.96	2.44	17.41	2.48	38.54	33.59	7.92	2.77
Lucerne (Medicago sativa)	215	7.15	15.62	2.30	33.78	34.10	7.05	2.49	16.82	2.47	36.40	36.72	7.59	2.68
Cowpea-vine hay	267	11.26	12.63	1.33	40.43	29.57	4.75	2.02	14.24	1.50	45.57	33.33	5.36	2.27
Cowpea-vine hay	159	14.54	12.56	1.75	39.91	23.68	7.56	2.00	14.68	2.04	46.70	27.70	8.84	2.33
Cowpea-vine hay[4]		11.07	15.68	2.87	42.17	19.80	8.41	2.30	17.63	3.22	47.41	22.26	9.45	2.58
Crimson clover hay (Trifolium incarnatum)	172	5.91	15.13	1.50	42.64	27.16	7.66	2.42	16.08	1.59	45.32	28.87	8.14	2.56

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[2] Average of three analyses.
[3] Average of 210 analyses.
[4] Average of six analyses compiled by Dr. E. H. Jenkins in the Conn. Sta. Rept. for 1888.

TABLE II.—CONTINUED.

		Parts in 100 of fresh or air-dry substance.							Parts of 100 in water-free substance.					
	Laboratory number.	Water.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.
4. LEGUMINOUS PLANTS—*Continued.*														
Crimson clover hay (Trifolium incarnatum)	262	10.85	16.05	2.29	37.14	25.45	8.20	2.56	18.01	2.57	41.67	28.55	9.20	2.87
Red clover hay (Trifolium pratense) nearly ripe	207	8.47	10.62	3.26	35.04	36.40	6.21	1.69	11.60	3.56	38.28	39.77	6.79	1.73
Red clover hay (Trifolium pratense) in bloom[5]		15.35	12.05	3.48	37.63	25.99	5.50	1.92	14.23	4.16	44.45	30.70	6.48	2.26
Mammoth clover	223	4.24	10.00	2.20	35.56	43.65	4.35	1.59	10.44	2.30	37.14	45.58	4.54	1.66
Soja (soy) bean hay	225	6.73	17.50	6.90	31.77	32.30	4.80	2.80	18.76	7.40	34.07	34.63	5.14	3.00
Soja (soy) bean silage	311	74.20	4.05	2.23	6.95	9.70	2.84	0.64	15.71	8.66	26.96	37.65	11.02	2.48
Bush clover (Lespedeza vioceæ), ripe	203	10.37	5.62	2.06	36.72	40.83	4.40	.90	6.27	2.30	40.97	45.55	4.91	1.00
5. PEANUT PLANT; VINES, NUTS, KERNELS, AND HULLS.														
Peanut-vines and leaves (tops)	196	6.25	10.31	5.46	50.36	20.33	7.29	1.65	11.00	5.82	53.73	21.68	7.77	1.76
Hulls of fruit of peanut	165	10.78	8.63	.92	18.49	56.54	4.64	1.38	9.67	1.03	20.73	63.37	5.20	1.54
Kernels of fruit of peanut	322	4.87	29.07	48.79	12.42	2.93	1.90	4.66	30.57	51.29	12.97	3.18	1.99	4.89
Peanut—whole fruit (calculated)		6.57	23.19	35.01	14.17	18.38	2.70	3.71	24.82	37.47	15.16	19.67	2.88	3.97
6. COTTON-SEED AND PRODUCTS AND COTTON STALKS.														
Whole raw cotton-seed	309	17.51	14.48	19.38	25.41	20.30	2.90	2.31	17.56	23.50	30.81	24.61	3.52	2.81
Whole roasted cotton-seed	310	9.32	16.09	22.48	25.78	24.03	2.26	2.57	17.75	24.80	28.44	26.51	2.50	2.84
Meal from roasted cotton-seed	138	3.53	24.00	33.61	22.57	11.11	5.18	3.84	24.87	34.83	23.39	11.50	5.36	3.98
Cotton-seed meal[6]		7.74	38.78	10.25	30.20	6.37	6.66	6.20	42.03	11.10	32.63	6.92	7.22	6.72

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[5] Analysis by New York State Experiment Station, Eighth Annual Report.

[6] Average of four analyses.

TABLE II.—CONTINUED.

	Laboratory number.	Parts in 100 of fresh or air-dry substance.							Parts of 100 in water-free substance.					
		Water.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.
6. COTTON-SEED AND PRODUCTS AND COTTON STALKS.—*Continued.*														
Cotton-seed hulls[7]		11.50	4.15	2.92	39.14	39.87	2.38	0.66	4.70	3.31	44.23	45.06	2.70	.75
Cotton stalks, burrs and leaves	140	12.77	7.31	2.27	42.35	27.55	7.75	1.17	8.33	2.60	48.54	31 57	8.88	1.34
Cotton stalks, burrs and leaves[8]									6.36	1.16	41.37	45.13	5.98	1.02
Cotton-seed kernel (hand separated)[9]		6.27	29.25	36.55	19.52	4.38	4.03	4.68	31.21	39.00	20.82	4.67	4.30	4.99
Cotton-seed hulls (hand separated)[9]		9.16	2.19	.58	38.67	47.12	2.28	.35	2.41	.64	42.57	51.87	2.51	.38
Whole cotton-seed	309	17.51	14.48	19.38	25.41	20.30	2.90	2.31	17.56	23.50	30.81	24.61	3.52	2.81
7. RICE AND BY-PRODUCTS; BUCKWHEAT AND BARLEY.														
Rice straw (hand separated)	189	9.02	4.69	1.91	37.74	33.19	13.45	.75	5.15	2.10	41.49	36.48	14.78	.82
Rice chaff (hand separated)	191	8.42	2.19	.67	31.83	37.95	18.94	.35	2.39	.73	34.76	41.44	20.68	.38
Rice grain (hand separated)	190	7.86	9.75	2.00	77.40	1.50	1.49	1.56	10.58	2.17	84.00	1 63	1.62	1.69
Rice flour or meal	332	10.34	5.95	1.92	58.32	16.92	6.55	.95	6.63	2.14	65.04	18.87	7.30	1.06
Rice polish	333	11.20	11.20	2.10	64 99	6.59	3.92	1.78	12.61	2.36	73.18	7.42	4.41	2.01
Rice chaff	334	9.32	1.61	.68	39.15	41.23	8.01	.26	1.77	.74	43.17	45.46	8.83	.28
Rice straw	335	11.97	5.86	2 08	33.72	38.61	7.76	.94	6.65	2.36	38.30	43.86	8.81	1.06
Buckwheat, whole plant, ripe	224	6.63	5 62	1.20	34.42	44.50	7.63	.90	6.02	1.28	36.87	47.66	8.17	0.96
Barley, whole plant, ripe	226	3.40	4.38	2.17	45.08	40.40	4.57	.70	4.53	2.24	46.68	41.82	4.73	0.72
8. OKRA PODS AND SEED.														
Okra pods	197	6.00	4.75	.79	32.86	47.60	8.00	.76	5.05	.84	34.97	50.63	8.51	.81

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[7] Average of five analyses.

[8] Analysis by Tennessee Experiment Station, Vol. IV, No. 5.

[6] Annual Report, North Carolina Station, for 1882.

TABLE II.—CONCLUDED.

	Laboratory number.	Parts in 100 of fresh or air-dry substance.							Parts in 100 of water-free substance.					
		Water.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.	Total protein (N×6.25).	Fats (ether extract).	Nitrogen-free extract.	Crude fiber.	Ash.	Total nitrogen.
8. OKRA PODS AND SEED—*Continued.*														
Okra seed	198	7.06	21.25	15.12	24.41	26.35	5.81	3.40	22.86	16.26	26.28	28.35	6.25	3.66
Pods and seed (calculated)		6.43	11.44	6.59	29.44	38.99	7.11	1.83	12.23	7.04	31.46	41.67	7.60	1.95
9. SUNFLOWER-SEED.														
Hulls of sunflower-seed (Mammoth Russian)	195	10.00	3.75	1.56	27.52	54.87	2.30	.60	4.17	1.73	30.58	60.96	2.56	.66
Hulls of sunflower-seed (Black Giant)	193	10.50	4.37	3.41	27.09	52.00	2.63	.70	4.88	3.81	24.69	63.69	2.93	.78
Kernels of sunflower-seed (Mammoth Russian)	194	6.90	29.37	43.92	13.00	2.65	4.16	4.70	31.54	47.17	13.98	2.84	4.47	5.05
Kernels of sunflower-seed (Black Giant)	192	6.85	31.56	41.75	15.94	2.50	1.40	5.05	33.89	44.82	17.11	2.68	1.50	5.42
Whole sunflower-seed, Mammoth (calculated)		8.45	15.84	21.53	20.71	30.29	3.18	2.53	17.30	23.52	22.62	33.09	3.47	2.77
Whole sunflower seed, Black Giant (calculated)		8.84	16.74	20.85	22.01	29.49	2.07	2.67	18.36	22.87	24.14	32.36	2.27	2.93

7. *Rice, and By-Products, Buckwheat, and Barley.*—The hand-separated portions of the rice plant, the compositions of which are presented under this head, were made from a large bundle collected by Mr. McCarthy near Wilmington at the time of cutting. The parts of the plant and milling products were obtained from the National Rice Milling Company, of Wilmington, N. C., through the courtesy of Mr. Norwood Giles, the general manager. Of the milling products, the flour or meal is the first portion taken off the grain by the pestles, while the "polish" is an inner layer, removed in the process of polishing the grains. This table furnishes data for comparing the composition and feeding value of parts of the rice plant as separated in manufacture, and as separated by hand, though it is to be remembered that the samples separated in the two ways were not from the same field. Of course the products from the mill are the only ones of commercial importance, the hand-separated parts being of interest merely in showing the composition of the parts as they actually exist in the plant, and not mixed with other portions.

The analyses of rice straw show it to be fully equal in feeding value to oat straw. It contains more protein, a little less fat, and about the same amount of nitrogen-free extract as oat straw. The rice chaff, however, is markedly inferior to either of the above. The whole rice grain is, in a high degree, a farinaceous food; starch makes up fully three-fourths of its weight, but it also has a fairly good percentage of protein. Rice "flour or meal," being the first portion taken off the grain, is more or less contaminated with chaff, and will vary in composition accordingly. Its analysis here shows it to be a good carbonaceous food resembling corn meal, but of less value. The average composition of oats and the composition of the sample of "rice polish" presented here do not differ materially. The "polish" contains about the same amount of protein, less fat, and more nitrogen-free extract than oats, and is consequently a splendid food.

The buckwheat and barley plants, the compositions of which are also shown, were obtained from specimens on exhibition at the Southern Exposition in 1891. The grain was full-ripe, and hence the analyses do not show the composition of the plants, as they would ordinarily be cut to feed as a whole, but as harvested for separating the mature grain.

8. *Okra Pods and Seed.*—The composition of okra hulls and seed is shown in the table. The seed are rich in protein and fats, while the hulls are low in their content of these substances. The proportion of hulls and kernels in the sample separated by hand for analysis were: pods, 59.5 per cent.; kernels, 40.5 per cent. The composition as presented in this table is of the whole seed, while the pods are the hulls, or outer covering in which the seed grew.

9. *Sunflower-seed.*—The sunflower has been grown in Russia for a great many years, and since 1842 on a commercial scale. There are two kinds grown there—one with small seeds used for the produc-

tion of oil, which has "superseded all other vegetable oils in many parts of Russia, and the other with large seeds, consumed by the common people in enormous quantities as a dainty." The cultivation is considered profitable there, the average yield being about 1,350 pounds per acre. The oil from the sunflower-seed is obtained in Russia very much as cotton seed oil is in the United States, by separating the hulls from the kernels and expressing the oil from the latter. The sunflower-seed cake is a highly nitrogenous cattle food, and is largely exported to Germany and England for feeding purposes; the hulls, or shells, of the seed are used as fuel, while the seed-cups are fed to sheep*. In the table is shown the percentage composition of hand-separated (which is more complete than would be obtained by machinery) hulls and kernels of "Mammoth Russian" (large striped) and Black Giant (small black) sunflower-seed, and hand-separated hulls and kernels of cotton-seed for comparison with corresponding parts of sunflower-seed. These analyses show the hulls of both varieties of sunflower seed to contain more protein, fats, and crude fiber, and less nitrogen-free extract than cotton-seed hulls, and indicate that they are at least equal, if not superior, to cotton-seed hulls as a cattle food, while the kernels contain more oil than the kernels of cotton-seed, and, together with the other nutrients, show that after the oil is expressed, the sunflower cake left will be fully up to, if not better, than cotton-seed cake as a food-stuff.

Percentage of parts of	Cotton-seed	Hulls, 50 per cent.
		Kernels, 50 per cent.
	Mammoth Russian sunflower-seed	Shells, 52.9 per cent.
		Kernels,47.1 per cent.
	Black Giant sunflower-seed	Shells, 54.5 per cent.
		Kernels, 45.5 per cent.

The percentages of parts of the two varieties of sunflower-seed were obtained by the separation of the seeds analyzed, and are subject to change with further investigation. These percentages with the chemical compositions of the parts presented in the table show that whole cotton-seed and whole sunflower-seed do not differ materially in composition.

Sunflower-seed were sent out to quite a number of co-operative field experimenters by the Station last season, but results of yields are not yet in shape for publication. The average yield in five experiments in as many parts of the State in 1889 was about 65 bushels per acre.

The results of weighings of one lot each of Mammoth Russian and Black Giant sunflower-seed at this Station gave 26.7 pounds per bushel for the former, and 32 for the latter. The Mammoth Russian seed, according to our analyses, contain 21.53 per cent. of oil, and the Black Giant 20.85 per cent. One bushel of the former would therefore contain 5.75 pounds of oil, and the latter 6.67 pounds of oil.

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*Abstract Jour. Soc. Chem. Ind., May, '92, p. 470.

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Dup

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INVESTIGATIONS UPON THE PHOSPHORIC ACID IN CRUDE FERTILIZER MATERIALS, AND UPON METHODS OF FERTILIZER ANALYSES.

Publications will be sent to any address in North Carolina upon application.

N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

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INVESTIGATIONS UPON THE PHOSPHORIC ACID IN CRUDE FERTILIZER MATERIALS AND UPON METHODS OF FERTILIZER ANALYSES.

I. ON THE AVAILABLE PHOSPHORIC ACID IN FISH SCRAP, TANKAGE, AZOTIN, DRIED BLOOD, BONE MEAL, AND COTTON-SEED MEAL, AND THE METHODS USED IN ITS DETERMINATION.

By B. W. KILGORE and R. E. NOBLE, Assistant Chemists.

The following investigations were made with a three-fold object—

1. The estimation of the available phosphoric acid in the several fertilizer materials.
2. The effect of fineness upon the available phosphoric acid in them.
3. The methods to be used in determining total, soluble, and insoluble phosphoric acid in these materials.

1. *Available Phosphoric Acid.*—Fish scrap, bone meal, and cotton-seed meal are sold quite largely in this State, both alone and in mixed goods, and all the other fertilizer materials are sold to a greater or less extent in mixed fertilizers. No claim is made for available phosphoric acid in any of them when on sale as such, but in mixed goods their available phosphoric acid, of course, appears along with that of the acid phosphate, or other phosphoric-acid-yielding material. This Station has heretofore estimated 2.5 per cent., 4 per cent. and 3 per cent. for the amount of available phosphoric acid in cotton-seed meal, tankage, and fish scrap respectively. The results of the analyses here reported confirm the practical correctness of this assumption, as will be seen by reference to the table, though tankage is subject to very wide variations in this respect. Our average results show the available phosphoric acid to be, in fish scrap 3.08 per cent, tankage 5.17 per cent., beef azotin 2.54 per cent., pork azotin 1 00 per cent., dried blood .71 per cent., bone meal 6.01 per cent, and cotton-seed meal 2.65 per cent.

2. *Fineness.*—The factor of fineness appears to have had little or no influence on the amount of phosphoric acid dissolved by cold distilled water and "ammonium citrate solution" (the available phosphoric acid), except in the case of bone meal, where there is an average difference of .51 per cent. in favor of the samples put through the 40-mesh seive, which is approximately 40 meshes to the linear inch. The average results of all the others, except beef azotin, where they are the same, are slightly higher for the 40 than the 20-mesh seive, but the differences are rather too small to be taken into consideration. Cot-

ton-seed meal was not put through the 40-mesh seive because of its low insoluble, and it is not likely that it would be changed by such treatment.

3. *Methods.*—The idea has long existed in the minds of analytical chemists that the nitric and hydrochloric acid methods, either alone, modified, or combined, are not safe for getting phosphates in organic materials into solution in the form to be readily precipitated by the ammonium molybdate solution. The trouble has usually been credited to the organic matter of the organic materials yielding phosphoric acid "playing tricks" with the molybdate solution. That these methods are inadequate for total phosphoric acid in cotton-seed meal no one now doubts. The object of the investigation was to ascertain if this difficulty extended to other vegetable and animal materials containing phosphates commonly used as fertilizers and in mixed goods.

The total phosphoric acid in the results here reported was determined (1) by dissolving the material in nitric acid and a little hydrochloric acid, and (2) by igniting with magnesium nitrate, dissolving the residue in hydrochloric acid and a little nitric, and following the present official method of the Association of Agricultural Chemists for phosphoric acid. It will be observed that there is practically no difference in the results by the two methods with any of the materials except cotton-seed meal, which was already known to exist. The magnesium nitrate method was not used on the bone meal, since numerous experiments here and elsewhere have shown the nitric and hydrochloric acid method to be perfectly safe for it, where care is taken in getting the solution.

Soluble phosphoric acid was determined (1) by direct precipitation of the water extract of the materials, and (2) by evaporating the water extract to dryness, igniting gently, dissolving the residue in hydrochloric acid and a little nitric, and proceeding as indicated above for total. Here, as in the case of total, there is seen to be, on an average, very little difference in the results by the two methods, save with cotton-seed meal, where the difference is marked and important.

Insoluble phosphoric acid was determined (1) by the regular official method of igniting both the "citrate-insoluble" residue and filter in a small platinum dish, dissolving the ash in hydrochloric acid and a little nitric, and (2) by treating the filter and citrate-insoluble residue directly in a 200 c. c. flask with nitric and hydrochloric acids. This latter method, though not a recognized official one, has been in use in this laboratory for at least four years, during which time numerous comparisons of it with the official ignition method upon all the fertilizer materials and mixed goods coming on our market have been made, and we have yet to find either a mixed fertilizer or fertilizer material that will give results materially different by the two methods. Cotton-seed meal, which has been the source of so much trouble in phosphoric acid work, is not even an exception to this general rule, which may seem somewhat strange, in view of the differences in total and soluble by similar methods on the same material. In operating on cotton-seed meal, we have, in fact, generally gotten a few hundredths lower by the ignition than by the nitric and hydrochloric acids method, due, no doubt, to the unavoidable slight loss in incinerating and transferring. All the phosphate in cotton-seed meal not immediately precipitable by molybdic solution is dissolved by citrate solution. The materials operated and reported on here embrace about the complete list of raw organic materials yielding phosphoric acid on sale in our State, either as mixed goods or alone, and the results, besides giving us a better knowledge of their available phosphoric acid and fertilizing value, serve to strengthen our confidence in the modification of the official method for insoluble. It does not give so nice a solution with organic materials as the ignition method, but the saving of time, where much work is being carried on, is not inconsiderable

So far as methods are concerned the following conclusions are drawn from the results (table I) on the materials here examined:

1. That, for total phosphoric acid, the nitric and hydrochloric acids and magnesium nitrate methods are equally reliable for all the materials, except cotton-seed meal, where the magnesium nitrate, incineration, or sulfuric acid and potassium nitrate method, or some of its modifications, must be used.*

2. That, for insoluble phosphoric acid, direct solution of the filter and citrate-insoluble residue in nitric and hydrochloric acids and official ignition methods are equally reliable for all the materials.

3. That, for soluble phosphoric acid, the results by the "ignition" and "direct precipitation" methods, compare fairly well in all the materials, except cotton-seed meal, where the ignition method is the only safe one.

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*See Bulletin No. 8, new series, S. C. Expt. Sta.

TABLE I. THE AVAILABLE PHOSPHORIC ACID IN SOME RAW FERTILIZER MATERIALS.

Laboratory Number.	FERTILIZER MATERIAL.	TOTAL BY METHOD		SOLUBLE BY METHOD		INSOLUBLE BY METHOD		Avail'ble, 20-mesh seive	Avail'ble, 40-mesh seive
		HNO_3 and HCl.	Ignition with Mg $(NO_3)_2$ and solution in HCl and HNO_3	Direct precipitat'n	Evap'ration, incineration and solution in HCl and HNO_3	Incineration and solution in HCl and HNO_3	Direct solution in HNO_3 and HCl.		
	Fish Scrap.	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*
421	Fish scrap through 20-mesh seive	7.52	7.54	.74	.92	4.28	4.31	3.24	
422	Same sample through 40-mesh seive	7.71	7.65	.78	.99	4.25	4.22	----	3.45
461	Fish scrap through 20-mesh seive	6.78	6.83	.38	.47	3.99	3.91	2.85	
436	Same sample through 40-mesh seive	6.65	6.69	.49	.55	3.91	3.86	----	2.79
	Average	7.16	7.18	.60	.73	4.11	4.07	3.04	3.12
	Tankage.								
415	Tankage through 20-mesh seive	----	10.81	.35	.51	6.88	6.75	4.00	
416	Same sample through 40-mesh seive	10.90	10.82	.54	.70	6.78	6.72	----	4.11
423	Tankage through 20 mesh seive	10.23	10.22	.38	.37	5.71	5.66	4.54	
424	Same sample through 40-mesh seive	10.36	10.30	.37	.42	5.72	5.70	----	4.62
	Average	10.49	10.54	.41	.50	6.27	6.21	4.27	4.36
6998	Tankage	15.61	----	--	--	----	9.39	6.22	
6999	Tankage	14.99	----	--	--	- --	9.08	5.91	
	Average of all	12.41	----	--	--	----	7.22	5.17	
	Beef Azotin.								
417	Beef azotin through 20-mesh seive	5.33	5.41	.64	.70	2.88	2.79	2.54	
418	Same sample through 40-mesh seive	5.39	5.27	.67	.65	2.75	2.84	----	2.54
	Average	5.36	5.34	.65	.67	2.81	2.81	2.54	2.54
	Pork Azotin.								
419	Pork azotin through 20-mesh seive	1.15	1.22	.75	.73	.22	.23	.96	
420	Same sample through 40-mesh seive	1.19	1.25	.75	.77	.17	.18	----	1.05
	Average	1.17	1.23	.75	.75	.19	.20	.96	1.05

TABLE I.—CONTINUED.

Laboratory Number.	FERTILIZER MATERIAL.	TOTAL BY METHOD HNO_3 and HCl.	 Ignition with Mg $(NO_3)_2$ and solution in HCl and HNO_3	SOLUBLE BY METHOD Direct precipitat'n	 Evaporati'n, incineration and solution in HCl and HNO_3	INSOLUBLE BY METHOD Incineration and solution in HCl and HNO_3	 Direct solution in HNO_3 and HCl.	Avail'ble, 20-mesh seive	Avail'ble, 40-mesh seive
	Dried Blood.	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*	*Pr ct*
425	Dried blood through 20-mesh seive	1.06	.93	.20	.24	.41	.32	.63	
426	Same sample through 40-mesh seive	1.02	1.07	.19	.23	.31	.19	....	.79
	Average	1.04	1.00	.19	.23	.36	.25	.63	.79
	Bone Meal.								
460	Bone meal through 20-mesh seive	20.66	....	..	.22	--	14.69	5 97	
435	Same sample through 40-mesh seive	20.72	....	.20	....	..	13.04	....	7.68
459	Bone meal through 20 mesh seive	21.21	....	--	.26	--	16.18	5.03	
434	Same sample through 40 mesh seive	....	....	.14	....	--	14.55	....	6.66
458	Bone meal through 20-mesh seive	23.35	....	.19	.24	--	17.08	6.27	
414	Same sample through 40 mesh seive	23 31	....	.18	....	--	16.85	....	6.46
	Average	21.85	....	.18	.24	--	15.38	5.76	6.27
	Cotton-seed Meal.								
437	Cotton-seed meal	....	2.62	.38	1.28	.20	.18	2.43	
438	Cotton-seed meal	....	2.98	.32	1.20	.13	.15	2.84	
439	Cotton-seed meal	....	3.02	.27	1.13	.13	.15	2.88	
6890	Cotton-seed meal	....	2.62	--	....	.15	.20	2.45	
	Average	....	2.81	.32	1.20	.15	.17	2.65	
	Cotton-seed meal	2.25	3.19						
	Cotton-seed meal	1.99	2.83						
	Cotton-seed kernels	1.69	2.37						
	Extracted cot.-s'd kernels	2.22	4.36						
	Average	2.06	3.19						

II. SOME EXPERIMENTS ON THE EFFECT OF WASHING THE MAGNESIUM-AMMONIUM-PHOSPHATE PRECIPITATE UPON THE PER CENT. OF P_2O_5

By B. W. KILGORE, Assistant Chemist.

In the analysis of high grade phosphates and mixed fertilizers the error from incomplete washing of the white precipitate with dilute ammonia water is more common, we think, than is generally recognized. This source of error may affect light as well as heavy precipitates, but it is more liable to do so, and be larger with high ones, as they are more difficult to wash thoroughly. During the past three years quite a number of experiments have been made in this laboratory on this point, but most of the results have not been preserved. A few, made at different times, but not with a view of publication, are presented in the table below (table II), and will serve to illustrate our point, though they do not show the full magnitude of the differences that may and do, we think, occur from incomplete washing when the per cent. of P_2O_5 reaches 20 per cent. or more. We have, in fact, had differences greater than the ones here presented to occur, and on phosphates no higher in phosphoric acid than the ones on which these results were obtained. Differences of .20 per cent. to .50 per cent. may easily occur in some precipitates between 10 or 12 and 15 or 18 washings. It is hardly necessary to say that there is a very great difference in magnesium-ammonium phosphate precipitates, even from the same material and solution, as to the ease or difficulty with which they can be freed from chlorids, depending on the excess of "magnesia mixture," conditions of precipitation, kind of precipitate (crystalline or amorphous), and other things, for aught we know, but just where the greatest difficulty lies, and how to overcome it, we do not venture to say, but that such difference and difficulty exists we have no doubt. We have had two precipitates from the same material, precipitated at different times and under different conditions, one of which could be freed of chlorids with 12 or 15 washings, while the other would require 20 or even 25; but where the precipitations are made at the same time and under the same conditions there is nearly always close agreement in the per cent. of P_2O_5 with equal amounts of washing, even when not free of chlorids. When the P_2O_5 is above 10 per cent. we do not feel safe with less than 18 or 20 good washings, stirring the precipitate well each time with the stream of wash solution, and then we test occasionally to see if the precipitates are clean.

This difficulty would not occur where the Gooch crucible is used to catch the precipitate, certainly not to the same extent as where paper is used.

TABLE II. THE EFFECT OF WASHING THE MAGNESIUM-AMMONIUM-PHOSPHATE PRECIPITATE UPON THE PER CENT. OF P_2O_5

	MATERIAL.	Number of washings.	Total P_2O_5	Total P_2O_5, duplicate	Average.	Difference between the least and highest number of washings.	Name of Chemist.
			Pr ct.	*Pr ct.*	*Pr ct.*	*Pr ct.*	
No. 1.	Acid phosphate	8	14.64	14.84	14.74		Noble.
No. 1.	Acid phosphate	21	14.16	14.01	14.08	.66	Noble.
No. 1.	Acid phosphate	Free of chlorids.			14.13		Meng.
No. 2.	Mixed fertilizer	8	11.44				Noble.
No. 2.	Mixed fertilizer	21	10.44	10.48	10.46	.98	Noble.
No. 2.	Mixed fertilizer	Free of chlorids.			10.45		Meng.
No. 3.	Mixed fertilizer	10	10.14				Meng.
No. 3	Mixed fertilizer	25	9.85			.29	Meng.
No. 4.	Mixed fertilizer	10	10.40				Meng.
No. 4.	Mixed fertilizer	25	10.00			.40	Meng.

III. ON THE TOTAL AND WATER-SOLUBLE POTASH IN COTTON-SEED MEAL.

BY B. W. KILGORE AND R. E. NOBLE, ASSISTANT CHEMISTS.

During the past fertilizer season three samples of cotton-seed meal, collected by the inspectors (the same samples as used in the phosphoric acid investigations reported in a preceding article), were analyzed by the incineration method with sulfuric acid for total potash, and by boiling in water for the water-soluble, with the following results:

Laboratory Number.	MATERIAL.	POTASH, K_2O	
		Total.	Water-soluble.
437	Cotton-seed meal	1.53	1.20
438	Cotton-seed meal	1.74	1.46
439	Cotton-seed meal	1.93	1.77
	Average	1.73	1.48

CONCLUSION.—85.5 per cent. of the total potash in these samples of cotton-seed meal was soluble in water.

IV. SOME FORMS OF APPARATUS IN USE IN THE NORTH CAROLINA EXPERIMENT STATION LABORATORY.

By B. W. KILGORE, Assistant Chemist.

1. Hydrogen Generator and Hydrogen Bath.

The hydrogen generator consists of the large aspirator bottle C, raised above the bottle D, drying bottles, connecting and drainage tubes. C is partly filled with hydrochloric acid just strong enough not to fume (we use 1.11 S. G. acid), and D is filled above the contraction with either lump or granulated zinc. The siphon tube E is about $\frac{3}{8}$ inch glass tubing and extends to the bottom of both C and D. To start the apparatus open the cock A, and by blowing in the tube B force the acid over into D. The hydrogen thus generated passes through sodium hydrate first to remove any chlorine that might go over, and is dried by passing through two bottles of sulphuric acid, and finally through anhydrous copper sulphate in the balled U tube, and then goes to the bath. When the operation is through, the cock A is closed, and the pressure of the hydrogen in D forces the acid back into C. The spent acid may be drawn off either through F or G. Hydrochloric acid is preferred to sulfuric acid in that zinc chlorid is more soluble and does not clog the apparatus as does zinc sulfate. The height of C above D may be varied with the force desired. This distance in our apparatus is about $5\frac{1}{2}$ feet, and gives a brisk, steady current. This piece of apparatus is cheap and efficient, and may generally be easily made from pieces of apparatus in any laboratory.

The water-bath for drying in hydrogen is circular, double walled, 12 inches deep and 12 inches in diameter, with false bottom, inlet tube L (for hydrogen), which extends about 3 inches in the interior of the bath, exit tube K in top, which extends nearly to the bottom of the bath, an opening for thermometer, and the condenser tube I.

The bath is made air-tight by a projection on the top dipping into a groove filled with mercury or paraffin, made by soldering a piece of copper around the inside of the bath at the top, and shown enlarged in the cut at M. When mercury is used the groove must be coated with plaster of paris, as also the projection where it is soldered onto the top.

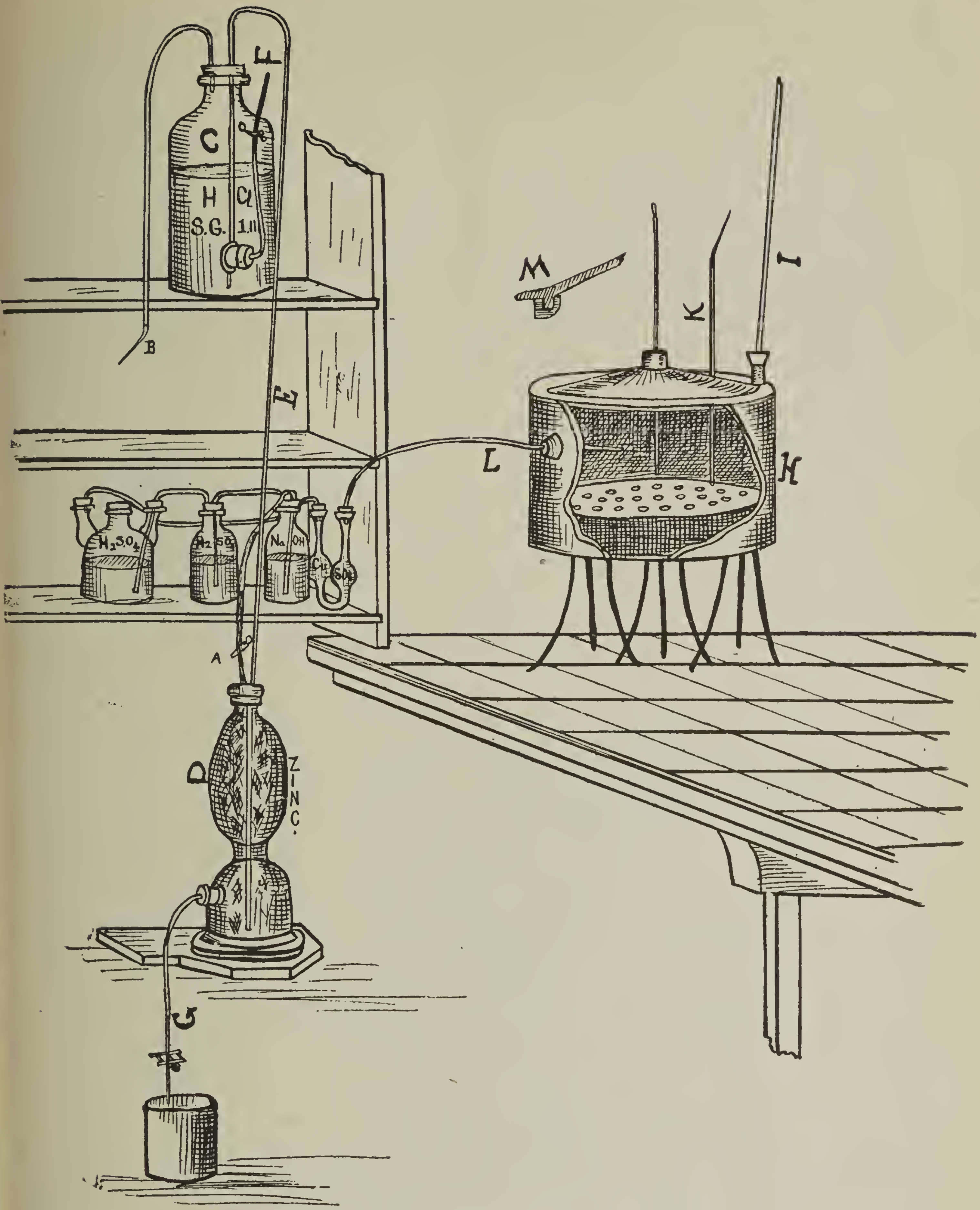
F
C
H Cl
S.G. 1.11
B
E
M
K
I
L
H
H_2SO_4
H_2SO_4
NaOH
Cu
SO_4
A
D
ZINC.
G

Fig. I.—Hydrogen Generator and Hydrogen Bath.

The top is weighted, and the hydrogen passing in through L fills the bath, beginning at the top and driving the air before it, after which there is a steady flow of hydrogen through the bath. The bath was intended to dry in an atmosphere of hydrogen, but it is large enough to put small pieces of apparatus on the false bottom, and connect them with the tube L, and thus dry in a current of hydrogen as well.

The interior of a bath of this size, and even much smaller, cannot be raised to the temperature of 100°C. by boiling water. We use a mixture of glycerol and water of such specific gravity as to give 100°C. The proportions of glycerol and water will depend on the size of the bath, and will have to be determined by experiment in each case.

2. Insoluble Phosphoric Acid Bath.

The bath is of galvanized iron, and sufficiently large to carry 12 flasks, which are held, as shown in the cut, in an upright position by means of spring clamps (A) at the top, and by fitting into the spaces of removed sections of the same size as the flasks of a skeleton disk (B) near the bottom of the bath.

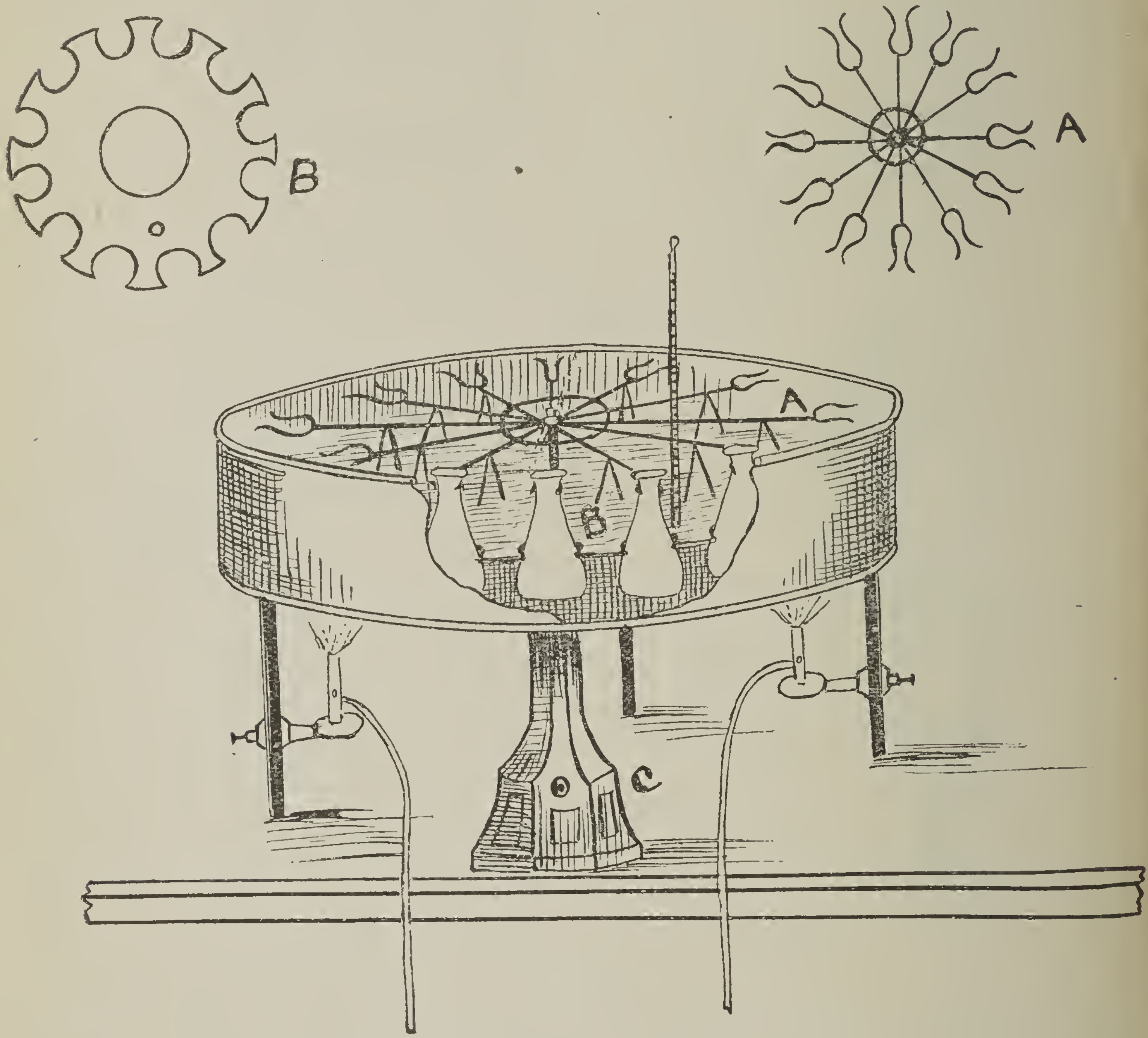

Fig. II.—Insoluble Phosphoric-Acid Bath.

The frame-work holding the flasks is fastened to the shaft of an ordinary fly-fan (C), by which the frame-work and flasks are revolved, thus agitating the water and keeping it at the same temperature in all parts of the bath, and making it easy to maintain a constant temperature in the bath as a whole. The spring clamps and skeleton disk are shown apart in the cut. We use about a 250 c. c. Erlemeyer flask, which fits nicely into our apparatus. The thermometer extends through the lower disk and nearly to the bottom of the flasks, which are about two inches above the bottom of the bath. The water in the bath comes nearly to the top of the flasks, which is two or three inches above the level of the citrate solution. This bath has been in use in this laboratory with good results for five years.

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TECHNICAL BULLETIN 8 SEPTEMBER, 1911

NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

OF THE

COLLEGE OF AGRICULTURE AND
MECHANIC ARTS

WEST RALEIGH

A SERIOUS LETTUCE DISEASE AND A METHOD OF CONTROL

Edwards & Broughton Printing Co.,
State Printers

N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS

THE NORTH CAROLINA
AGRICULTURAL EXPERIMENT STATION

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The Bulletins and Reports of this Station will be mailed free to any resident of the State upon request.

Visitors are at all times cordially invited to inspect the work of the Station, the office of which is in the new Agricultural Building of the College.

Address all communications to

N. C. AGRICULTURAL EXPERIMENT STATION,
West Raleigh, N. C.

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A SERIOUS LETTUCE DISEASE (SCLEROTINIOSE) AND A METHOD OF CONTROL*

By F. L. Stevens and J. G. Hall.†

PART I.

Lettuce, formerly a garden plant grown for home consumption, has of recent years become an important article of farm production, representing, says Mr. L. F. Kinney,[1] "a higher form of agriculture than any known to previous generations." Its production has so increased that in 1897 we find the statement that the "sales of this vegetable from a single farm during the last fifteen years have amounted to over a half million dollars."

This crop has been grown commercially in the United States for more than fifty years, and was the first crop to be grown extensively under glass by market gardeners.[1]

As early as 1872, it was estimated that no less than 50,000 sashes were used mainly for this purpose within ten miles of Boston.[2]

About 800 acres are now devoted to seed production in California alone, making some 400,000 pounds of seed.‡

Lettuce was first grown largely on a commercial scale in Connecticut and Rhode Island. It was estimated that in 1893 fully nine-tenths of the winter head lettuce sold in New York and other eastern markets was either grown in Rhode Island or in the vicinity of Boston.[3]

During the last decade there has been a large increase in the shipment from the South to the metropolitan markets, particularly from North Carolina and South Carolina where lettuce is grown under cloth, and from Florida where it is grown largely in the open. In Florida it was first cultivated under canvas about 1894, Mr. F. D. Warner, of Gainesville, and Mr. Denby being among the pioneers in this industry in that State, as was also Mr. J. E. Pace, of Sanford, who introduced the crop in that place in 1896.

Lettuce is now grown to a large extent in South Carolina, particularly at Conway where it was first grown about the year 1900. Charleston and James Island are other prominent lettuce centers in South Carolina.

The Lettuce Industry in North Carolina.

Wilmington was the pioneer lettuce growing community of North Carolina, and the first lettuce raised under cloth for shipment in this State seems to have been grown by D. W. Trask, of Wilmington, about 1892, three years before other commercial lettuce was produced in Wilmington. Mr. Trask, who raised lettuce in a small way for the home market, had more than could be sold there and was forced to ship it. This lettuce sold at from $6.00 to $10.00 a barrel and the area under cloth was increased the next year to more than an acre. After the third year others began raising this profitable crop, and the area gradually increased until it now aggregates between 75 and 100 acres under cloth.

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*The matter here published has in part been presented at various scientific meetings, American Phytopathological Society, Boston, 1909; the N. C. Academy of Science, Greensboro, May, 1908; the N. C. Academy of Science, Raleigh, May, 1911, and in part published in Bulletin No. 217, N. C. Agr. Exp. Sta.

†Mr. G. W. Wilson has taken the place of Mr. Hall during the last year of the work.

‡Letter from Mr. W. W. Gilbert, Bureau Plant Industry, who gives his information as coming from W. W. Tracy, Sr., of the Horticultural Office.

The leading lettuce growers of the Wilmington section are: W. H. Mills & Sons, F. D. Klein, W. E. Springer, H. L. Thorne, D. W. Trask, O. Martindale, C. E. Kerr, A. O. McEarchern, B. B. Trask, Moses Horne, F. T. Kerr, C. F. Seitter, Add. Hewlett, and Geo. W. Trask.

Around New Bern lettuce was first grown for market in 1894, by Mr. W. H. Bray with an area of about three acres, and Messrs. Hackburn and Willet with one acre.

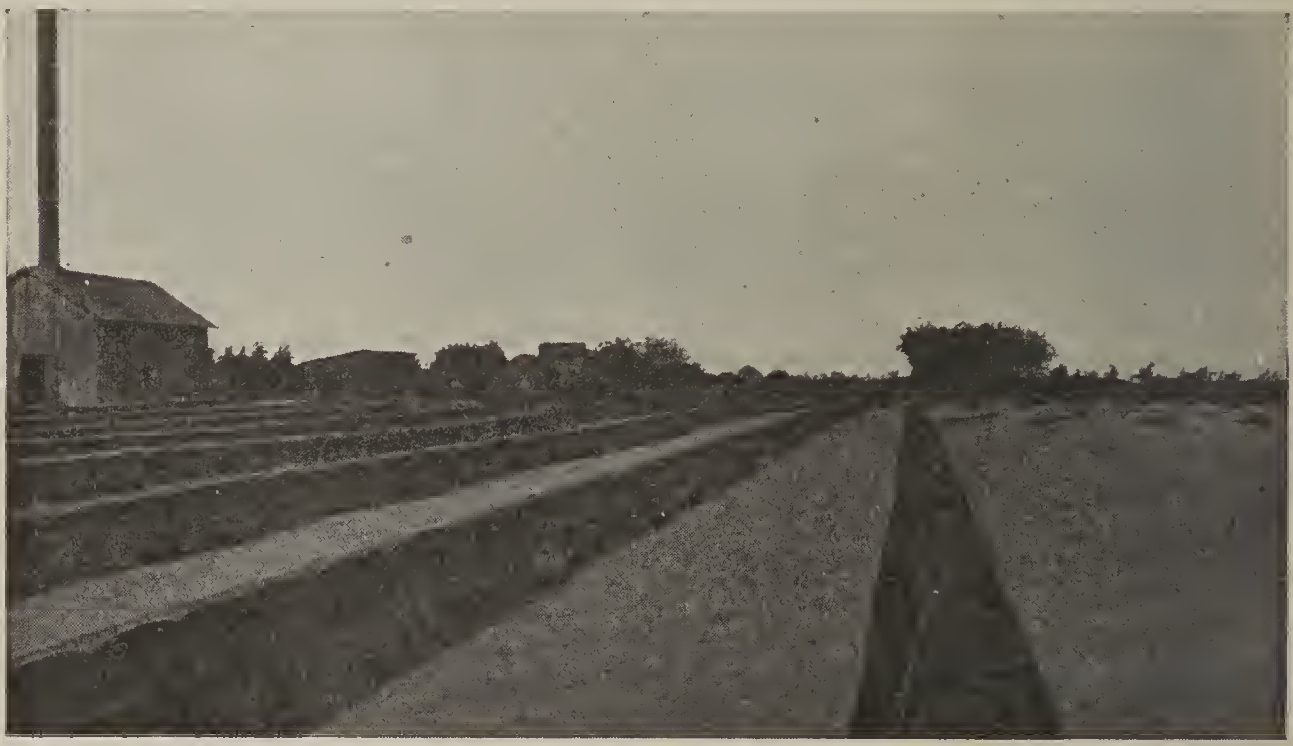

FIG. 1.—Lettuce as grown under canvas with irrigation at New Bern, N. C.

The acreage in the immediate vicinity of New Bern, all under cloth and irrigated and much of it steam heated, soon increased manyfold.

The most extensive growers of lettuce around New Bern are or have been, Hackburn & Willet, W. H. Bray, Edward Clark, J. M. Spencer, Thomas Daniels, H. H. Tooker, and J. A. Meadows.

At Fayetteville, commercial lettuce culture was apparently begun about 1895 by Fittzell Brothers with two thousand plants and the industry has increased rapidly, the crop at times totalling between 15 and 50 acres.

The principal growers are, or have been, W. H. Tomlinson, J. A. Pemberton, S. H. Strange, H. T. Drake, J. A. Nicholson, William Kyle, W. L. Hawley, Fittzell & Fittzell and many small producers, more than forty-five in all.

At Warsaw, about 1897, L. Middleton and J. A. Powell raised lettuce commercially. H. H. Caroton, Will Corbett, O. P. Middleton, J. A. Powell, Sr., J. A. Powell, Jr., Henry Middleton, of Warsaw;

and John Hamilton, Charlie Gore, Rob Wells, and Charlie Pickett, of Magnolia, are, or have been, prominent in the industry.

At Maxton, lettuce was grown for shipment in 1902 by H. C. McNair and H. S. McNair.

Considerable lettuce is also grown for shipment at Faison, Willard, Wade, Tarboro, Chadbourn, and Mt. Olive.

CHARACTERISTIC SYMPTOMS OF SCLEROTINIOSE.

Sclerotiniose may readily be distinguished from any other lettuce disease when the specific symptoms are once known.

Of these symptoms the one which first catches the eye of the lettuce grower is the rotting of his plant in whole or in part. When first observed a single leaf may be drooping, or wilting; a day or so later the whole plant appears involved, the outer leaves dropping flat on the ground, the central head alone remaining standing. At this stage the plant appears as though scalded by an application of hot water. The head also soon succumbs to the rot and topples over. The first conspicuous symptom is this rotting and "dropping" of the whole plant.

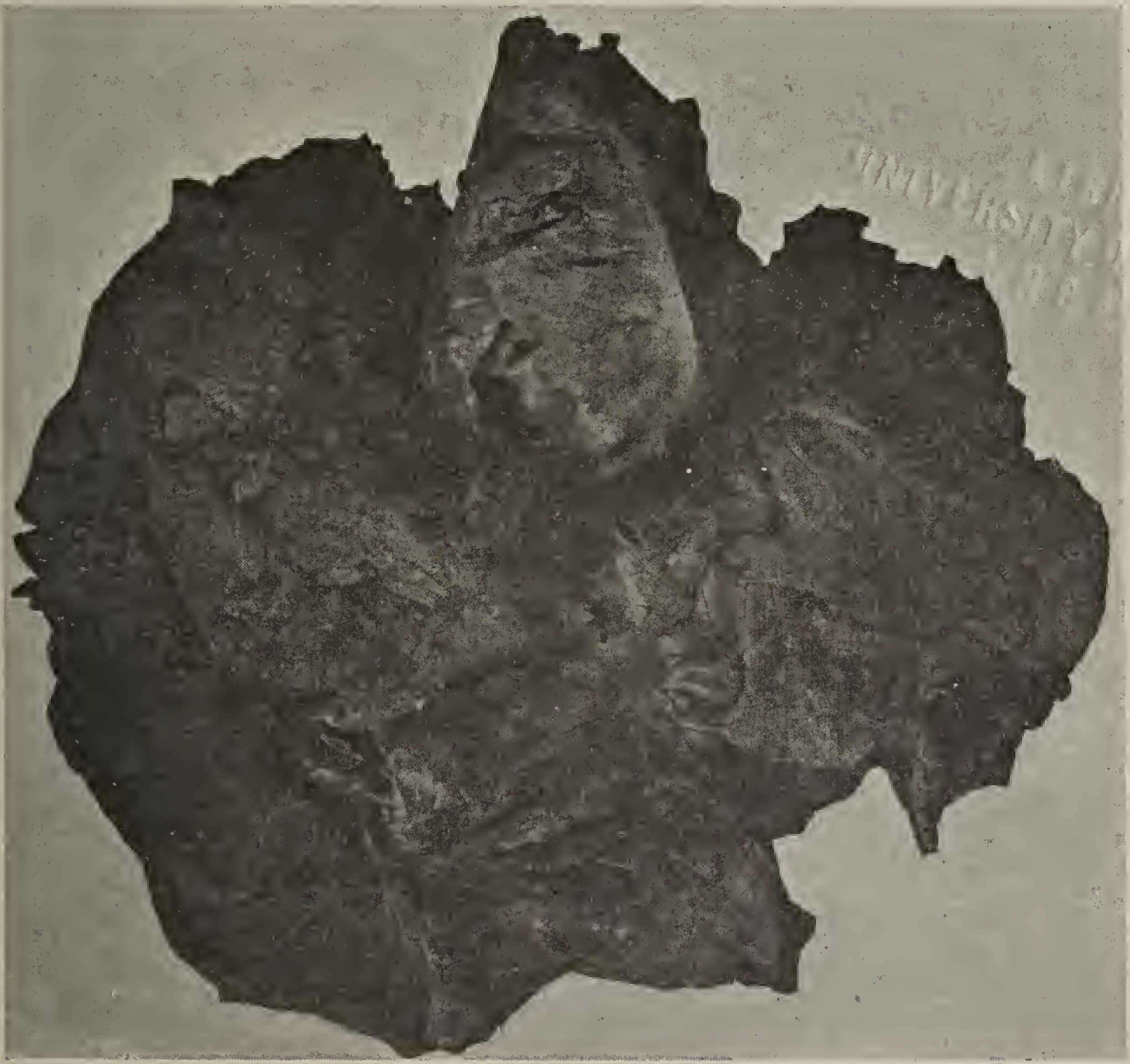

FIG. 2.—Plant showing drop, one symptom of sclerotiniose.

Close examination of such rotting plants, especially in the later stages of the disease, reveals the presence of a delicate weft of cotton-like threads on the underside of the affected leaves, especially in the more moist regions as at the base of the leaves near the stem. This character is limited to Sclerotiniose, and is a sure indication of this disease.

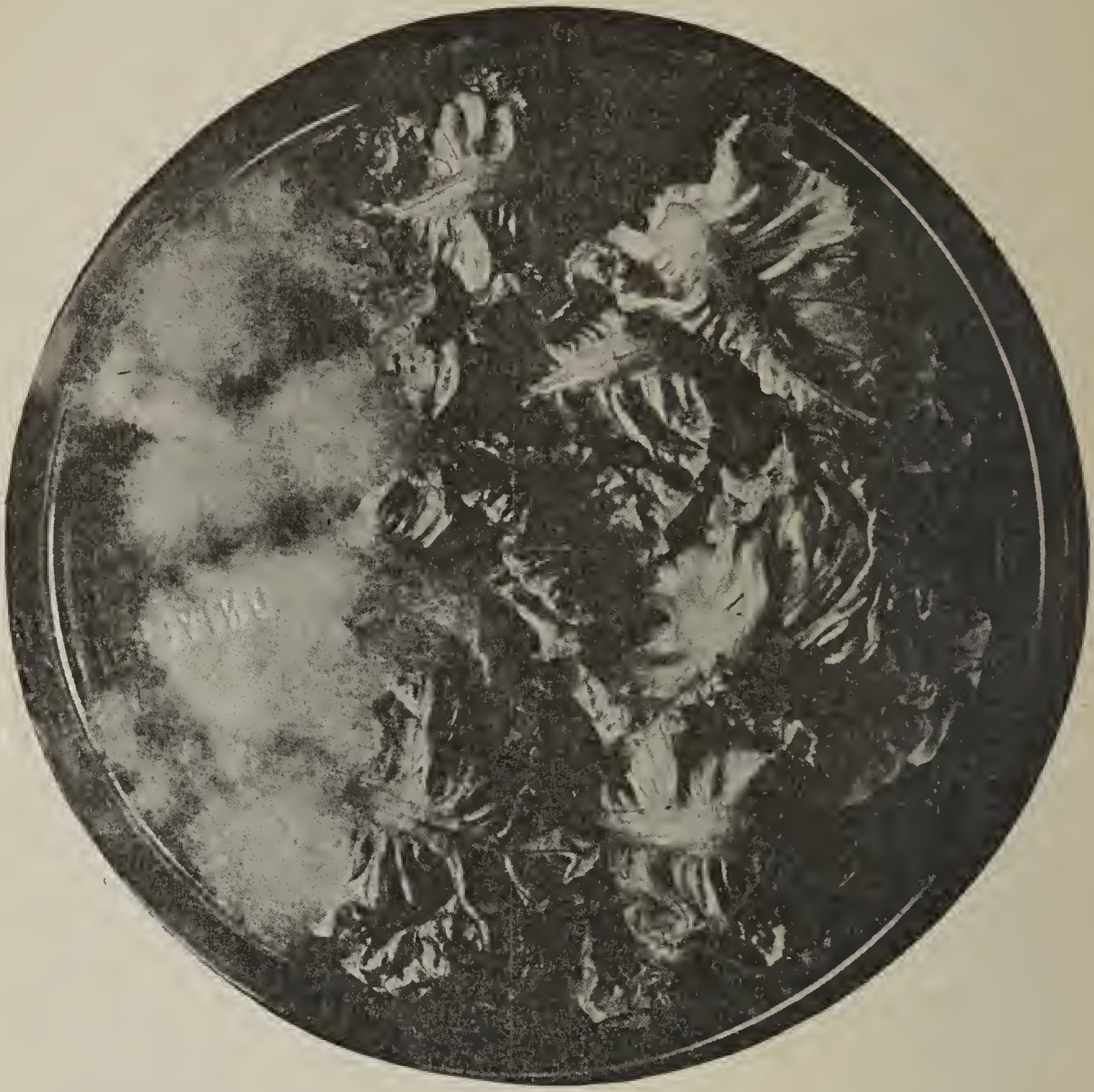

Fig. 3.—Sclerotiniose: mycelium growing upon leaves in culture dish. This cotton-like weft of mycelium is definitely characteristic.

In the last stages of the disease, a week or two after the final dropping of the plant, there will be found many small black bodies, varying in size from that of a pin head to a grain of corn, in, or upon, or under the sick portions of the plant. These too are absolutely characteristic of Sclerotiniose.

These three characteristics—the dropping, the cotton-like mycelium, and the sclerotia—if carefully observed, enable anyone to pronounce with certainty as to whether or not a given bed or plant is affected with Sclerotiniose.

History of Sclerotiniose in America.

The disease characterized by the symptoms indicated above is termed *sclerotiniose* from the fungus *Sclerotinia* which is its cause.

Since one of the chief symptoms of Sclerotiniose, the symptom which certainly first catches the eye of practical lettuce growers, is a dropping and rotting of the outer leaves, followed usually by dropping and rotting of the rest of the plant, this disease has come to be called "the drop," by lettuce growers in many sections of the country. These symptoms may be produced by several different causes.[4]

"The drop" is therefore not one single definite disease. It is rather a condition or a symptom just as lameness of horses is a condition or a symptom, not a disease. Lameness may be due to spavin, which is one disease, or to tuberculosis, which is another, etc. So the drop may be due to *Sclerotinia,* to *Pythium,* to *Botrytis,* etc., each of these causing a separate disease and each requiring different treatment and prophylaxis according to the nature of its cause.

The first definite knowledge of the existence of lettuce *Sclerotiniose* is contained in a communication by Smith in 1900.[4]

The disease is there first clearly and accurately characterized and attributed to its causal fungus, *Sclerotinia libertiana* Fckl. While 1900 is thus the earliest date of accurate knowledge concerning this disease, it was in all probability seriously injurious long before that time, and many serious lettuce troubles reported from different parts of the United States, and attributed to other causes, were doubtless really due to Sclerotinia. Sclerotiniose frequently occurs in conjunction with other lettuce diseases and in many instances inroads upon the lettuce beds attributed to *Botrytis, Rhizoctonia, Bacteria,* or other causes, were probably due in part, even in main, to sclerotiniose, often doubtless complicated by one or more of these other diseases. Among such early, but somewhat uncertain cases are the following:

Prof. G. E. Stone, of Massachusetts, says in a letter to the senior author (April, 1908), "I think we have evidence to show that the disease has been here a number of years, and that it is not a native in this region. It was doing considerable damage in the lettuce houses in the 90's—I think the fungus is not indigenous as it does not occur in some of our greenhouses in this State. I know many greenhouses which became infected with the drop through the introduction of plants from the Boston market-garden district. When I first studied the disease I had to introduce it into my greenhouse, and I knew of a number of houses at that time which never had it.

"I do not believe the disease troubled the very early lettuce growers, and I imagine it was not severe in the 90's. I do not believe the men who grew lettuce for 40 or 50 years had much trouble in growing it under sash or even in their old greenhouses. My predecessor in the station, Prof. Humphrey, I think probably had the same trouble under observation when he was here in 1888 or 1889, and probably some of the other observers who described the bacterial disease of lettuce, had the drop. I have always considered that Sclerotinia and eel worms were both introduced organisms, and were not indigenous to our State. What I have said in regard to the sclerotium being absent from some houses for many years, also applies to eel worms, since there are many houses which have never been troubled with these. I look upon many of these diseases as simply the result of extensive commercial relations with foreign countries."

J. E. Humphrey[5] in 1892 records a lettuce disease in Massachusetts which Smith[4] thought "covers what is now generally known in the lettuce district as 'the drop,'" though there is no real certainty that Humphrey had actually to do with sclerotiniose. The only evidence that his disease was such is that it occurs in a region where this disease was subsequently very prevalent, and that his description agrees with that of the drop.

L. H. Bailey[6] in 1895 pictured a lettuce plant which in the picture appears to be a typical case of drop. He attributed it to *Botrytis,* not to *Sclerotinia,* though it is possible that *Sclerotinia* was present and remained unnoticed.

A. D. Selby[7] in 1896 mentioned a disease as "lettuce rot" attributing it to *Botrytis.* This may have been a form of drop, and was possibly due in part of *Sclerotinia,* though there is no evidence that anything but *Botrytis* was present.

G. E. Stone and R. E. Smith[8] in 1897 described a disease which they called "the drop" and which they attributed to *Botrytis.* Though from their later paper it seems possible that this early outbreak was in part at least due to *Sclerotinia.*

In 1898 Stone and Smith[9] and again in 1899[10] refer to an outbreak of lettuce "drop," still attributing it to *Botrytis,* though it probably was in part, even largely, due to *Sclerotinia.*

H. Garman in 1899[11] speaks of lettuce rot, which from his description, seems to have been some form of drop. *Botrytis* and other organisms were seen, but *Sclerotinia* was not definitely mentioned.

True *sclerotiniose* was mentioned and figured in Hume in 1901.[12] He then said "within the last few seasons a disease has wrought considerable destruction to the crop. This disease is commonly known among the growers as 'damp off.' In some cases the attack resulted in the total loss of the crop, while in others a loss of from 25 to 50 per cent. was suffered."

The disease is said by Rolfs in a letter to one of the authors to have been severe in the region of Gainesville about 1896, at which time a number of fields were almost completely destroyed.

Ramsey in 1904[13] described a lettuce disease due to the presence of *Botrytis* on the fall crop and a genuine case of *sclerotiniose* on the second crop in later winter. It was clearly characterized by the presence of cottony mycelium and by sclerotia.

In North Carolina, the drop, probably in all cases true sclerotiniose, first attracted the attention of lettuce growers around New Bern in 1897; at Fayetteville in 1901; at Warsaw in 1902. It was mentioned by the senior author of this bulletin in his Annual Report of 1907,[14] and was the subject of a press bulletin in the same year.[15]

It is briefly referred to by Hutt in a bulletin of the North Carolina Department of Agriculture.[16]

Sclerotiniose is now known to occur, as is shown in the accompanying map, in all of the South Atlantic States, North Carolina, South Carolina, Alabama, Georgia, and Florida, and also in Maine, Vermont, Massachusetts, New York, Connecticut, Rhode Island, Pennsylvania.

Delaware, Louisiana, Wisconsin, Washington, and Iowa, and a partially verified record of its occurrence in Virginia exists. While not definitely recorded from other States, it probably occurs in many of them, particularly near the Atlantic seaboard.

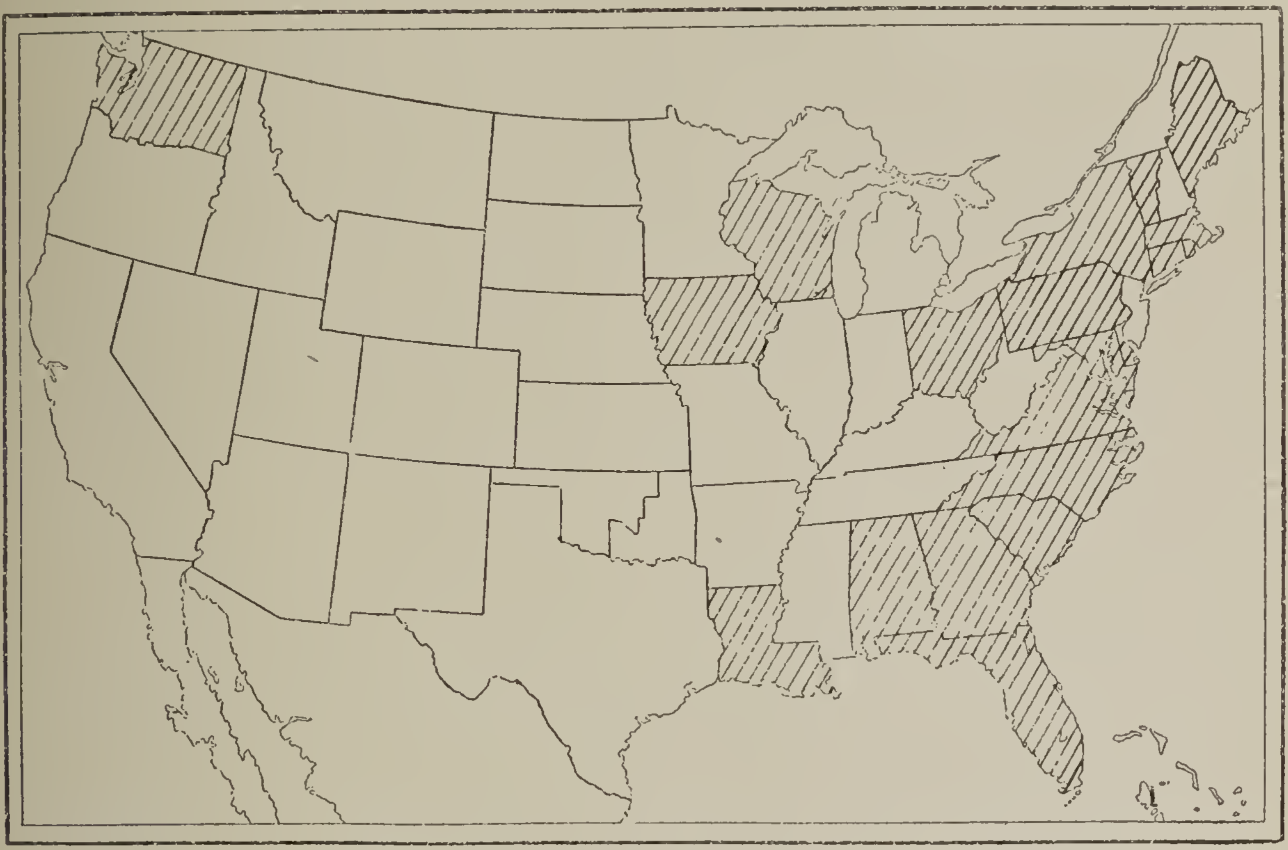

FIG. 4.—Map showing distribution of sclerotiniose in the United States. The disease is definitely reported in shaded States, but is not known to occur in others.

From what is known of the disease it is certain that it persists long and multiplies in territory once infected, and rapidly invades new regions. It is therefore increasing the area under its tribute yearly, and will continue to become of wider significance, especially as the lettuce industry broadens.

Summarizing the history of Scleriotiniose it may be said to have attracted attention first about 1890 in Massachusetts, in 1896 in Florida, in 1897 in North Carolina, in 1904 in Wisconsin, and to now possess practically the whole Atlantic seaboard and some of the more western States.

AMOUNT OF DAMAGE.

The extent of the damage varies with the severity of the epidemic and with the value of the crop affected. In 1900 in Massachusetts Stone and Smith[17] placed the proportion of plants succumbing to the disease at 15 to 85 or 95 per cent. of the crop. "The latter percentages are very exceptional, as growers are not content to experience this loss more than once without making radical changes in their methods. Practically entire crops have been destroyed by drop alone to our knowledge, and the majority of growers in Massachusetts have experienced at one time or another a loss of from 15 to 40 per cent. The loss of 25 per cent. from drop is no uncommon experience in a large number of lettuce houses, and when we consider that these houses each may contain from 6,000 to 12,000 plants, worth from 40 cents to $1.00 per dozen, some idea of the loss may be obtained."

In Florida* the loss is very severe and is sometimes complete. In South Carolina while crops are frequently destroyed and the lettuce industry seriously threatened as is shown in the following quotation from a personal letter.† "Several years ago I grew lettuce quite extensively for Northern markets, but had to give it up on account of the damping off. * * * Lettuce is not grown here as extensively as in former years principally on account of this disease."

In Maryland sclerotiniose does damage in many greenhouses.‡

In Alabama sclerotiniose is reported by Wilcox§ to do much damage in those places where lettuce is grown on a large scale. In Auburn and Montgomery it is repeatedly met, with great loss.

In New York, some growers, says Stewart** have had considerable trouble with the drop. It certainly is one of the troublesome diseases of lettuce." Whetzel, of the same State, says "it (the drop) occurs more or less commonly in all greenhouses about this State and sometimes in lettuce fields."

AMOUNT OF DAMAGE IN NORTH CAROLINA.

In North Carolina the lettuce "drop" or "damp off" now shows itself to greater or less extent at New Bern, Wilmington, Maxton, Fayetteville, Willard, Raleigh, and probably at numerous localities where lettuce is of less importance. The damage done by it in 1906 is variously estimated at 10 per cent., 20 per cent., 33 per cent., 50 per cent., and 70 per cent. by different growers. At Fayetteville the damage from this disease is estimated at from 10 to 50 per cent. of the total value of the crop. Around Wilmington the loss is placed at 10 per cent. At New Bern estimates vary from 33 1-3 per cent. to 50 per cent., while at Maxton the loss is placed at 20 per cent.

The disease sometimes appears the first season the crop is grown in a given soil, often not until many crops have been raised. When once it does gain a foothold in a bed it persists, multiplies and increases until usually the grower is forced to move the bed to new regions, usually to very soon meet again a similar fate. Thus the loss to the crop is coupled with the loss attendant upon moving the lettuce bed, frames, irrigating, and heating pipes to new land and the leaving of the enriched soil to go to a newer and poorer one.

CURSORY DESCRIPTION OF SCLEROTINIOSE.

The cause of the "drop" is a fungus belonging to the genus *Sclerotinia,* a genus which is well known on account of its many destructive species, among them being two that are particularly conspicuous, one causing a serious and widespread apple rot and the other causing one of the worst of peach diseases. The fungus is known technically as *Sclerotinia libertiana Fuckel.* It was first described in 1869, and bears its present name, libertiana, in honor of Marie Anne Libert who published on parasitic fungi from 1813 to 1837. The plant body of this fungus consists of delicate branching, mold-like threads called the mycelium, which may, with the microscope or if abundant with the naked eye, be seen in or on the affected parts of the lettuce plant. No diseased part is free from them and they are, on the other hand, never present without being accompanied by a condition of disease in the adjacent parts of the lettuce plant. It has been definitely proved beyond all peradventure that these fungous threads are the actual cause of the disease and that nothing else can cause this disease.

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*Letter from P. H. Rolfs, March 30, 1908.

†D. T. West, Charleston, S. C., May, 1907.

‡Personal letter from J. B. S. Norton, December 14, 1906.

§Personal letter from E. M. Wilcox, March 28, 1908.

**F. C. Stewart in personal letter, March 30, 1908.

This fungous mycelium, coming in contact with a lettuce leaf, exudes a poison which kills the near-by cells of the lettuce plant. The cell walls are then dissolved and the mycelium makes its way through or between them. It dissolves also the contents of the cells and absorbs the resulting nutrient solutions to further its own development. The mycelium thus grows larger, kills more cells, consumes them and continues to advance rapidly through the affected leaf until the whole leaf is a soft, slimy, rotten mass. The invasion continues into the main stem, then upward to the central bud and "heart" of the head, out into other leaves, downward through the root until every portion of the host plant has been killed, and the nutritious parts consumed.

Environmental conditions may, to some extent, change the course of the disease. The fungus grows best in abundant moisture. Sometimes this leads to a more rapid decay of the inner protected dry portion of the head, and a plant which to casual inspection appears healthy may prove upon close examination to be, at heart, a slimy, rotten mass. Again through one-sided infection the decay may progress much more rapidly upon one side than upon another, resulting in complete death of one side before the other shows any symptom of disease.

As a rule the mycelium is not visible to the naked eye on leaves until the nutriment within the leaves has been nearly or quite, exhausted by the fungus. When this time is reached the mycelium begins its external appearance as the loose cottony growth referred to above. The most profuse development of this aerial mycelium occurs in the region of more humid atmosphere, such for example as on the under sides of leaves lying upon the ground, between leaves, or at the bases of leaves, in fact anywhere that the air is so situated as to cause it to remain especially humid.

Soon after the appearance of the aerial mycelium in profuse quantity, it may be noted that in each region where the mycelium is dense there appear one or more centers of aggregation, composed of very densely intertangled and interwoven mycelial threads. These denser masses enlarge, increase in density and finally become solid masses of tightly compacted mycelium. These bodies are called *sclerotia.* The sclerotia are at first colorless, then pale salmon color, and finally black on their exterior and flesh colored within. When first formed they are buried in and covered by mycelium, and are only to be seen by tearing this mycelial covering away. As time passes this mycelium is lost, the remains of the lettuce plant disappear, and the only visible evidence of the plant or the fungus then is the sclerotia, many of which are produced in each sick plant.

The sclerotium germinates under suitable conditions, usually after a lapse of several months to nearly a year, under field conditions. This it does by sending forth several thread-like sprouts about one-thirty-second of an inch in thickness. These sprouts expand at the end developing a horn-like or cornucopia-like disk (Fig. 5) called the apothecium. This apothecium is, in the field, borne just at the surface of the ground with its face directed upward.

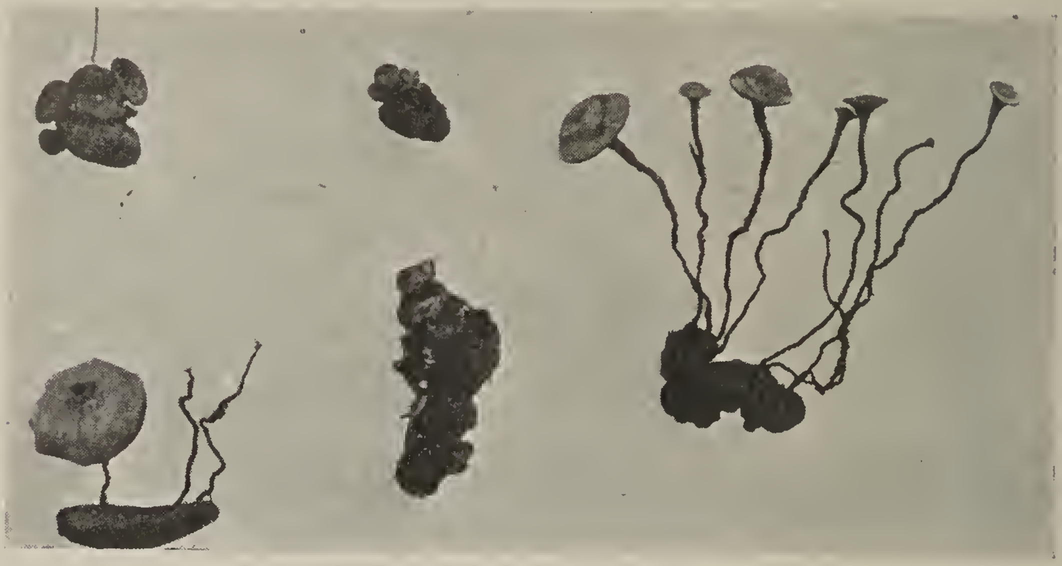


Fig. 5.—Sclerotia-bearing disks; natural size.

Microscopic examination of the apothecium shows its disks to consist of two parts: (1) lower basal part supporting (2) an upper layer which consists of very numerous small slender tubular bags, or sacs, the *asci.* (Fig. 6.) Each ascus when mature contains eight small oval bodies (Fig. 6) the *spores.* It is seen then that the apothecium is essentially an organ whose function is to produce myriads of spores.

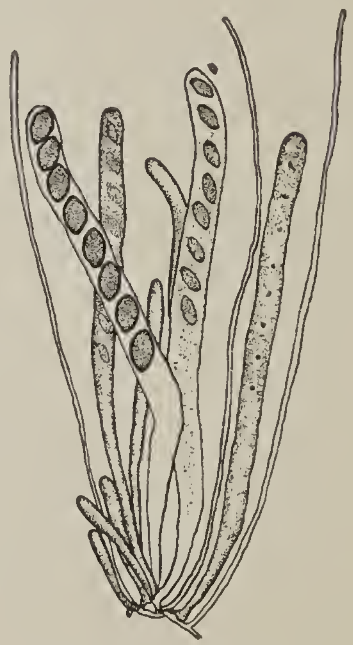


Fig. 6.—Asci and paraphyses in various stages of development.

When ripe these spores are ejected from the asci by pressure, being forced into the air often to a distance of several feet where, caught by air currents, they may be carried quickly to great distances. The spores under suitable surroundings, germinate and send forth small thread-like sprouts (Fig. 7). These sprouts, with suitable nourishing material, grow rapidly into a vigorous mycelium, which is again ready to invade the living lettuce plant; to again cause the drop.

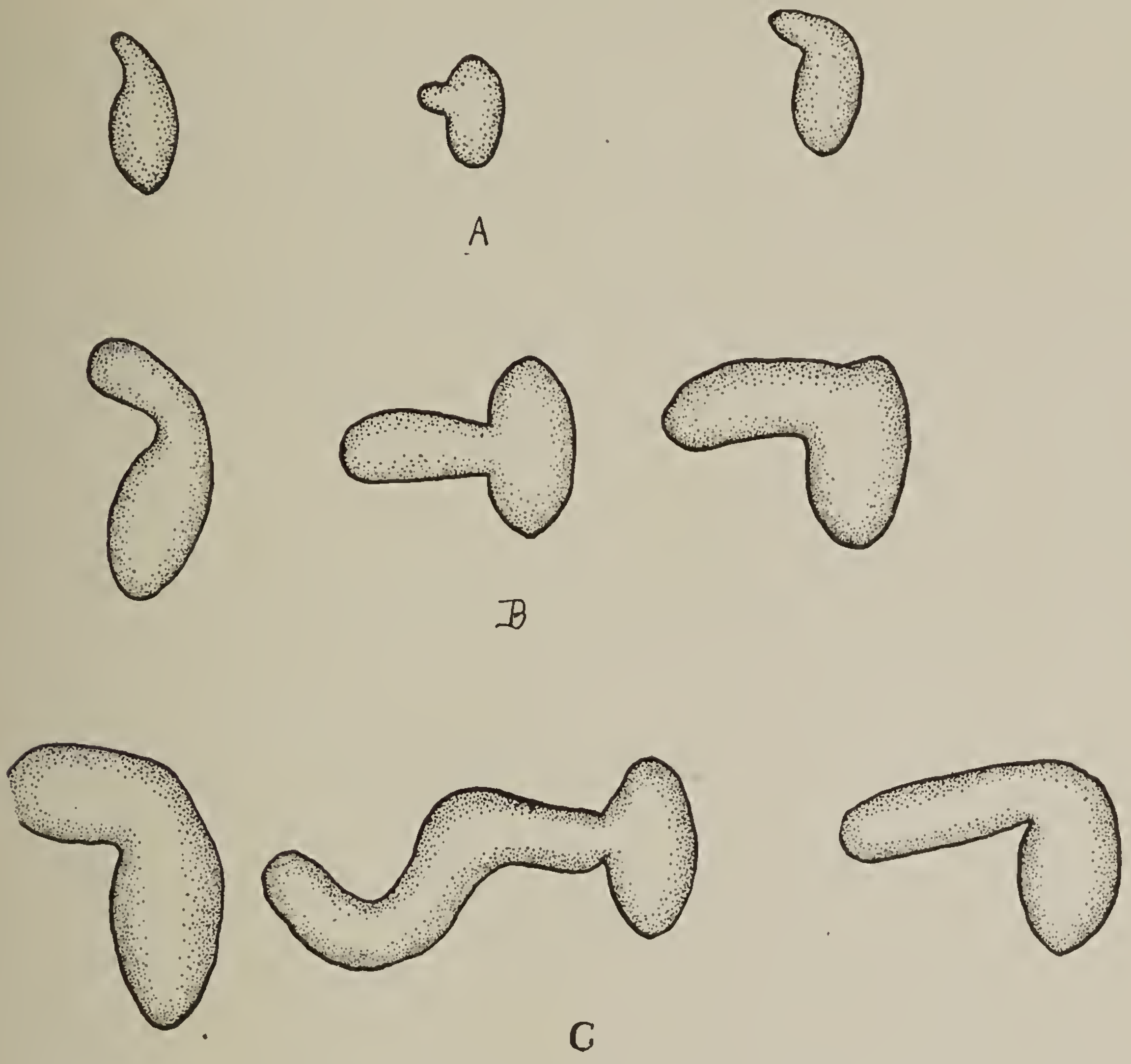


Fig. 7.—Ascospores germinating. *A*. At two hours; *B*, at five hours; *C*, at seven hours.

This history of the drop fungus may be epitomized by saying that the mycelium grows within the lettuce plant, causing the drop; produces sclerotia when nutriment is exhausted; rests in the sclerotial condition until opportune conditions prevail; the sclerotia then produce apothecia bearing asci in which are spores; these spores produce a new mycelium which again invades lettuce plants.

The Fungus That Causes the Disease.

Morphology.

The *mycelium* in gross, as developed external to the leaf in humid air, appears as a coarse cottony mass most abundant around the stem of the plant among the leaf bases. It is also found to a great extent upon the lower diseased leaves that lie upon the surface of the ground. It is more plentiful on the under sides of these leaves or between leaves if two or more are lying upon each other on the ground, but very seldom makes any extensive showing upon the ground itself unless under artificial conditions of excessive humidity.

The mycelium is comparatively large and coarse, varying in diameter from 5.8 μ to 14.5 μ with many septa (Fig. 8) which divide each mycelial thread into many cells, whose lengths vary with their position

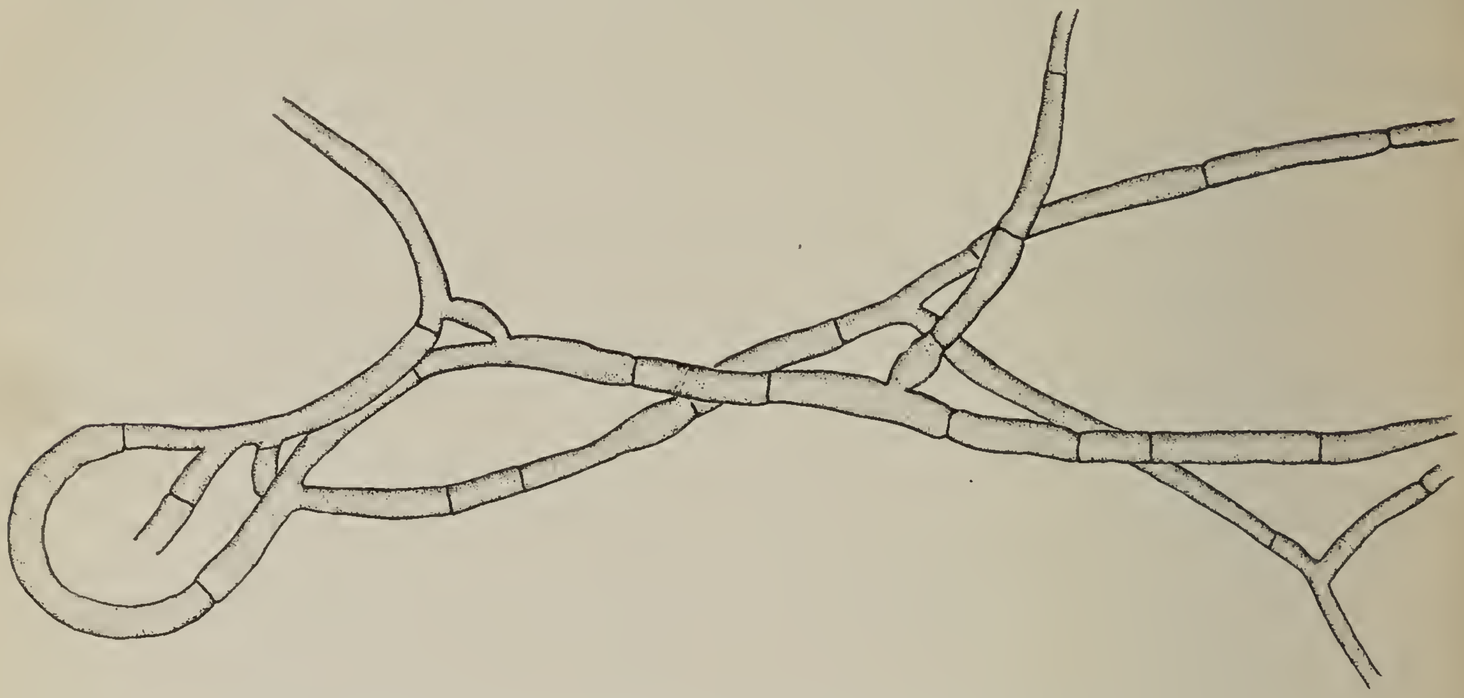


FIG. 8.—Mycelium showing septation and branching.

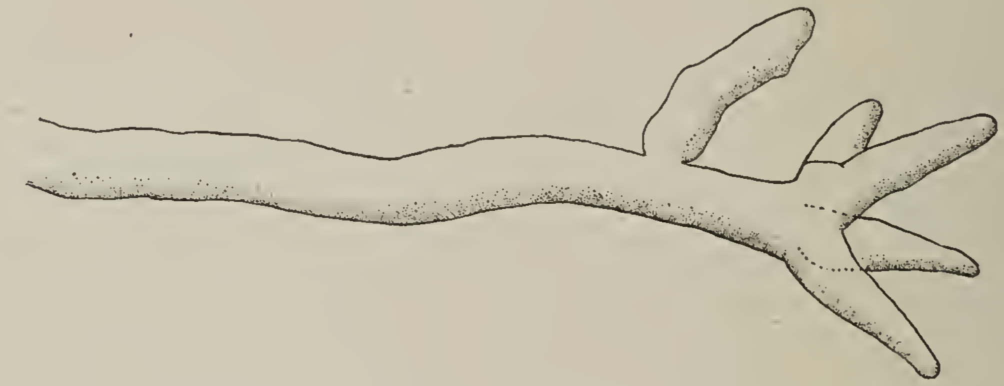


FIG. 9.—Mycelial thread, showing mode of apical branching.

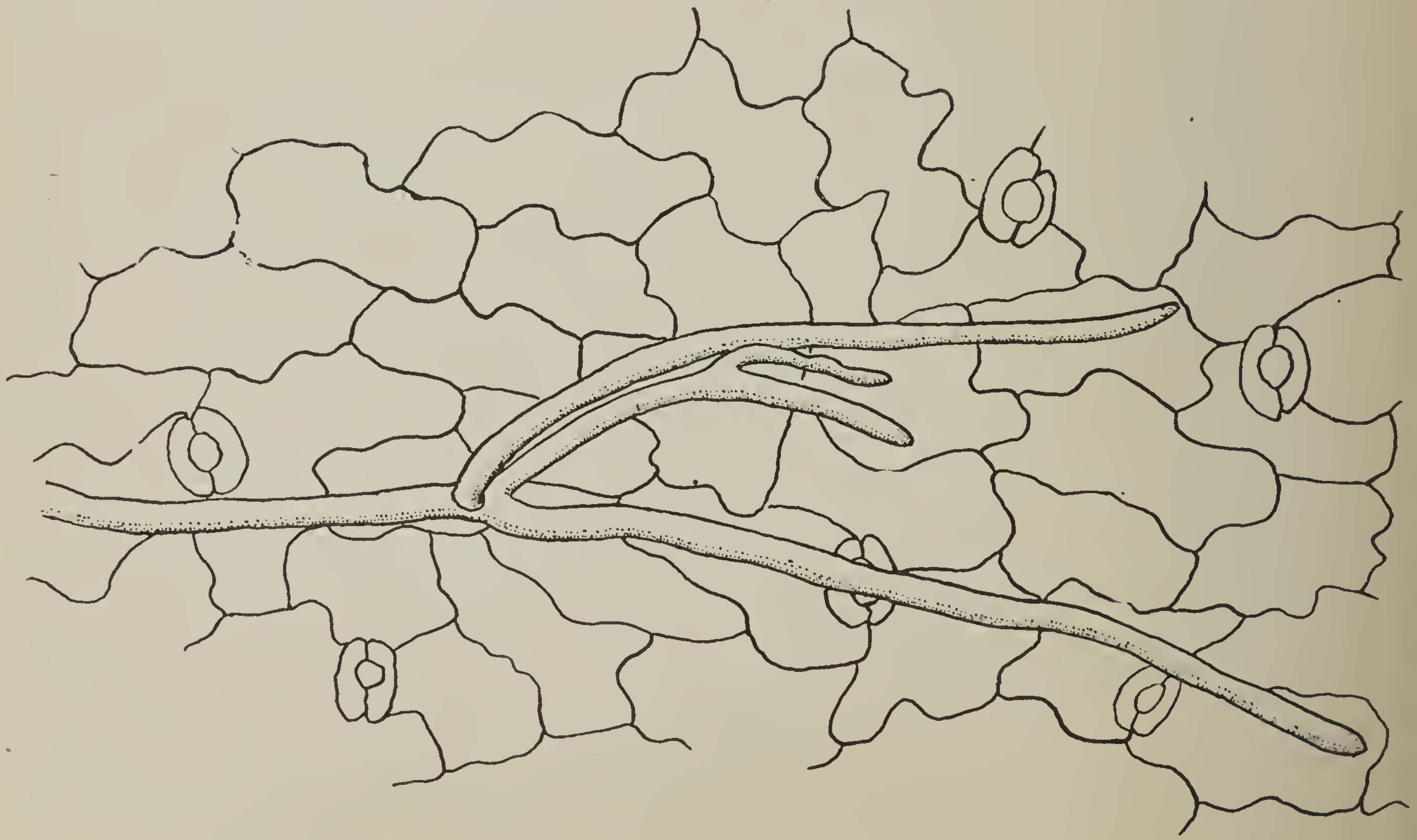


FIG. 10.—Lettuce leaf, showing stomata and superficial sclerotinia mycelium.

in the hypha. In the younger growing tips the septa are very far apart, and become closer in the older parts. There is no completely regular method of hyphal branching, although the greater number of branches seems to arise as perpendicular outgrowths near the end or middle of a cell, Fig. 8. There are two other methods of branching, one of which will be discussed under "attachments." The other is that in the case of a young hypha, which is growing rapidly and has an abundance of nourishment, in which case three or more branches arise, frequently simultaneously, and the main hypha loses its predominance; the three branches being equally vigorous. At first,

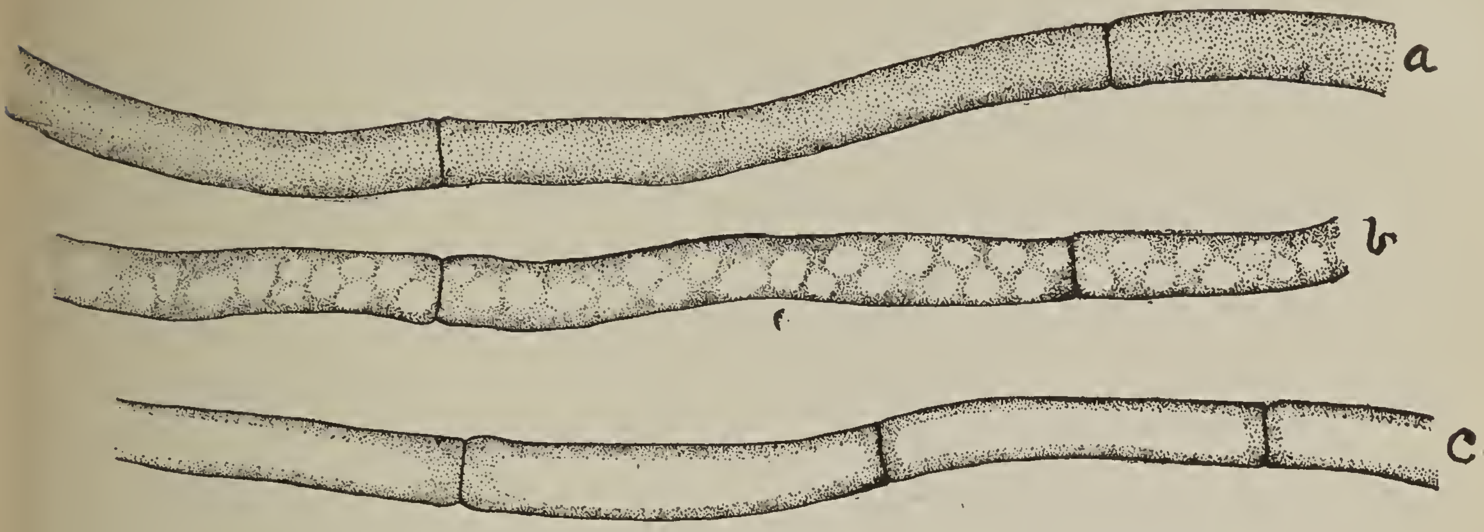


FIG. 11.—Mycelial thread showing three stages in its development; *a*, young; *b*, medium; *c*, old.

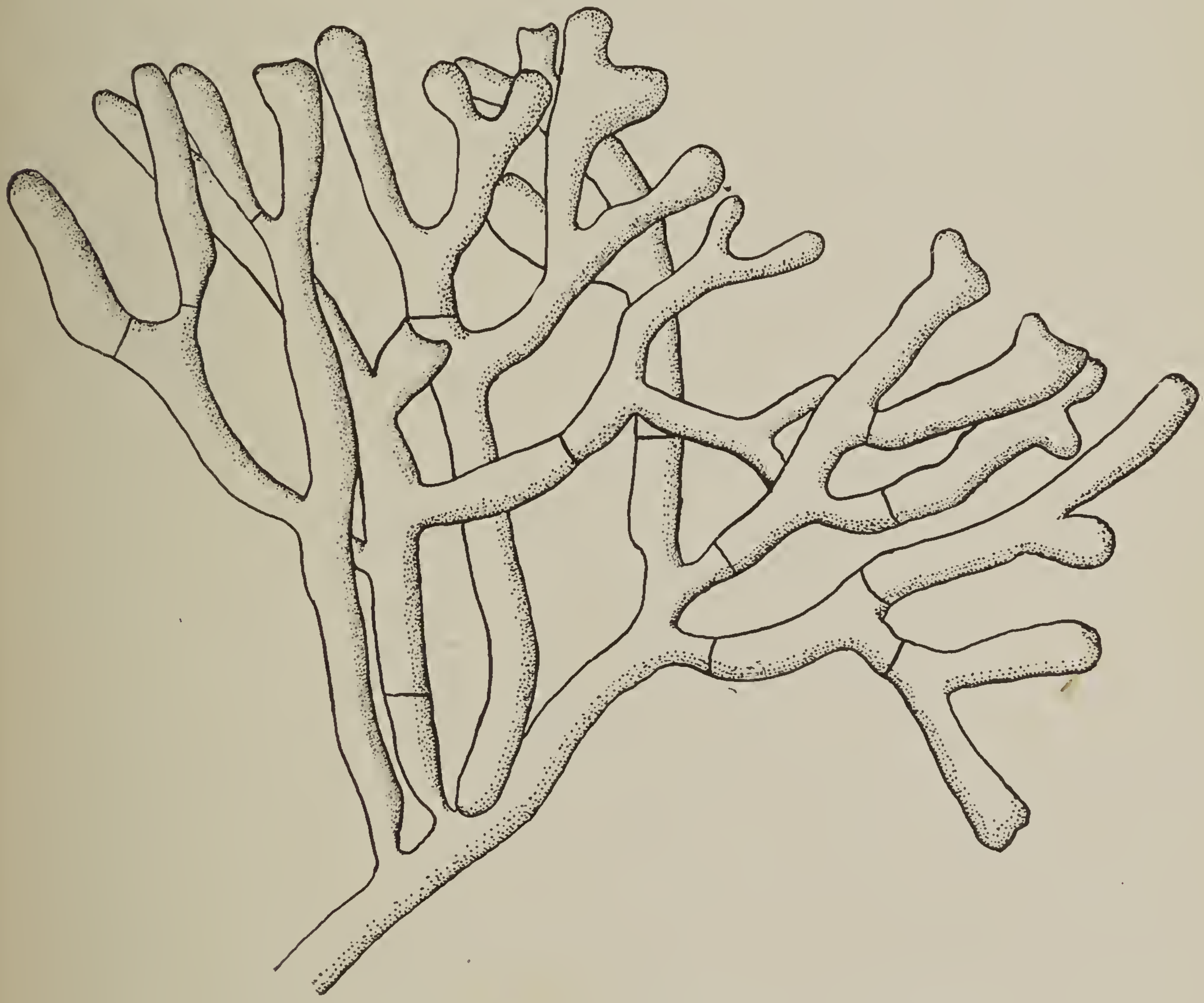


FIG. 12.—Mycelium showing branching to form attachments.

as in the youngest mycelium, the contents of each thread is a more or less homogenous mass, Fig. 11a, of protoplasm, but gradually as the hypha grows, there appears first a single row of vacuoles,

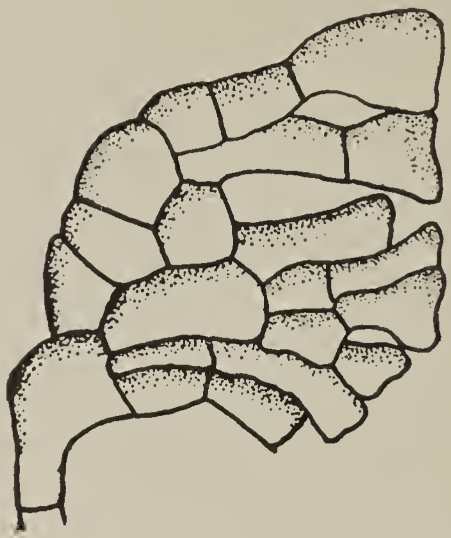


FIG. 13.—Portion of attachment organ showing flattening of the tips.

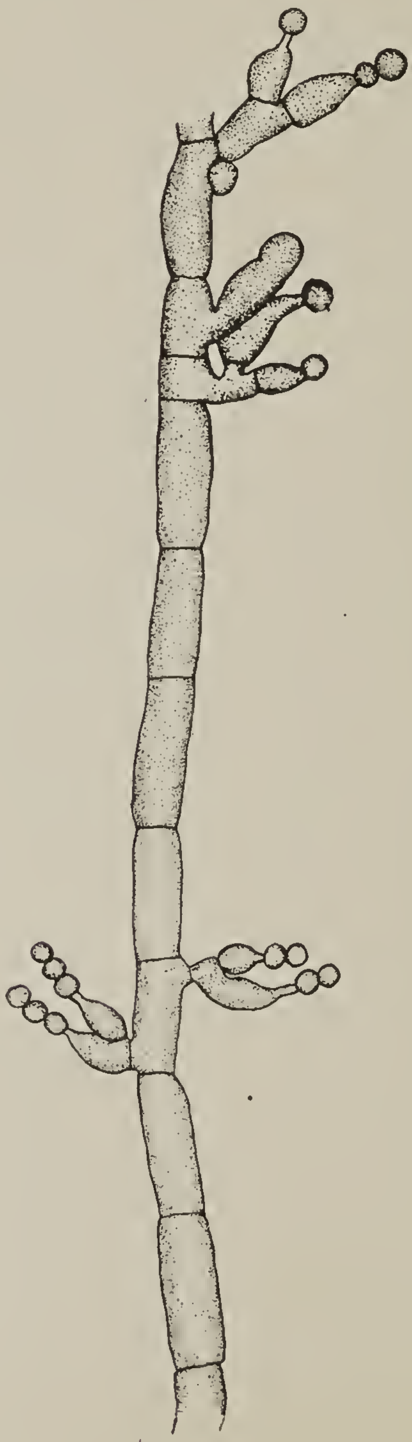


FIG. 14.—Mycelium showing method of production of gonidia.

Fig. 11b. These increase until the whole filament becomes very vacuolate, and finally all apparently coalesce to one large vacuole which nearly fills the whole of the cell, Fig. 11c.

The *attachments* first appear as numerous short branches from near the tip of an ordinary hypha. Each one of these primary off-shoots produces branches that again branch forming a rather compact mass, Fig. 12. They are at first continuous but very soon become septate.

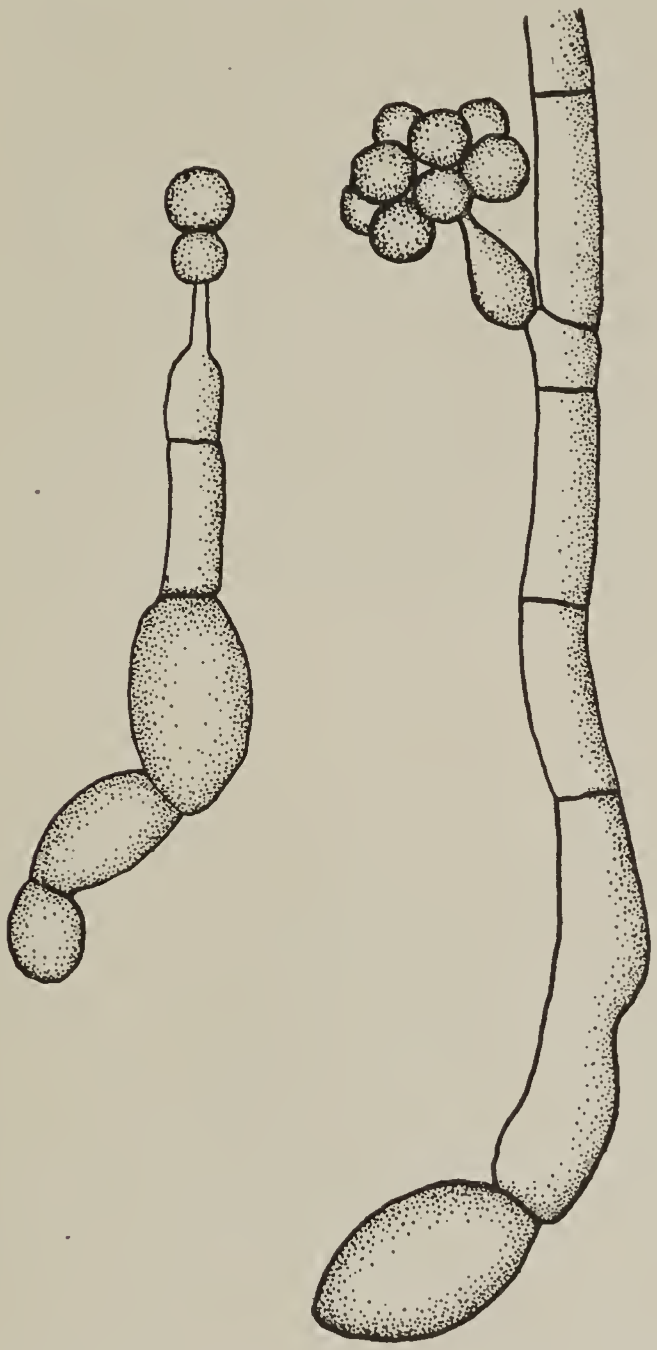


FIG. 15.—Germ tubes from ascospores producing gonidia.

With the appearance of the septa the tips of the branches enlarge. When they come into contact with some solid as a culture dish or a lettuce leaf, they become somewhat flattened, Fig. 13, on the end and apply themselves to and cohert to the substance.

Gonidia.—Frequently both in drop and in plate cultures there are found small spherical bodies, *gonidia,* that appear very much like spores, Fig. 14, although they have never been seen to germinate. They are highly refractive bodies, measuring about 2 to 3 mu in diameter, and are produced in large numbers in acropetal succession upon flask-shaped stalks. These stalks are produced either as lateral branches of an ordinary vegetative hypha or as the termination of such hypha. They are at times also produced in abundance upon the germ tubes formed by the ascospore, Fig. 15. In some cases several are formed close together, so that many gonidia are produced together, forming a large mass and completely hiding the stalks that bear them.

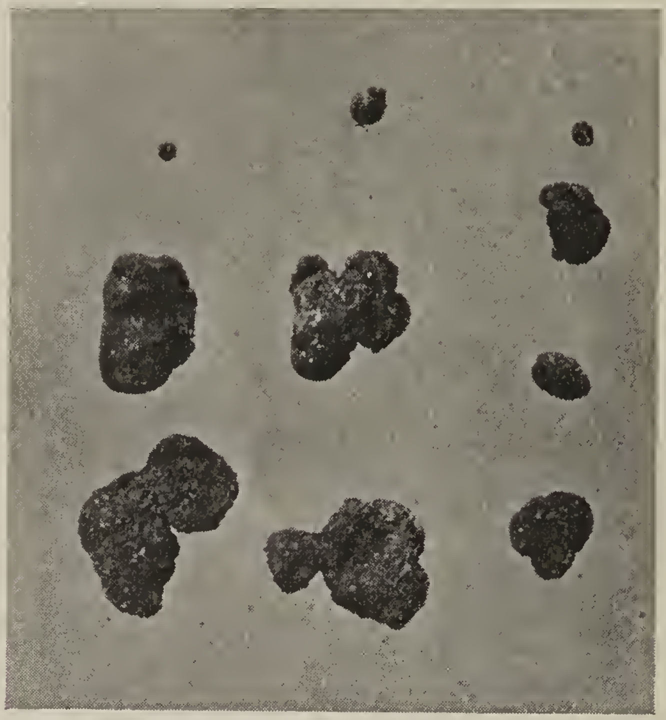


FIG. 16.—Sclerotia taken from one infected plant, showing variation in size.

Sclerotia.—Upon suitable media in the laboratory and upon plants in the field the purplish black resting bodies, the sclerotia, are formed. These vary much in shape, some of the smaller ones being almost spherical and some of the larger ones long, irregularly cylindrical or flat. In size there is also much variation, the smallest ones being no larger than a pin head, while the larger ones are larger than a grain

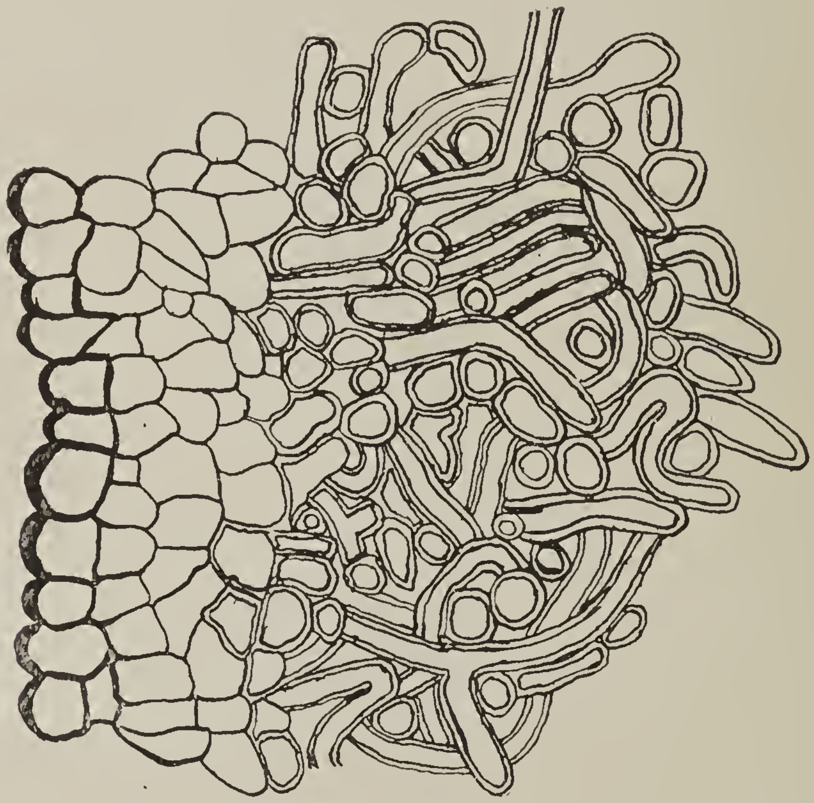


FIG. 17.—Section of a sclerotium showing parenchyma-like rind and modified mycelium of the interior.

of corn. The large and the small are however in nature and in normal cultures, produced indiscriminately together, and in no case was there a production of either large or small ones exclusively.

When first gathered from the field their average weight was determined as .06 grams each. After dying in the laboratory for a year they averaged .02 grams as determined upon a weighed hundred. They are somewhat rough on the surface and have a rather tough exterior protecting layer composed of two or three layers of parenchyma-like cells with thick, hard, black walls, Fig. 17. Internally the sclerotium consists of a compacted mass of mycelial threads, which do not vary perceptibly from the ordinary mycelium, except that they have much thicker walls and narrower lumen, Fig. 17, and their diameter is less than that of the vegetative hyphæ.

In cultures in the laboratory it was possible to follow the development of the sclerotia accurately. At first there occurs a massing of the mycelium, causing a white, somewhat raised bunch of mycelial threads, floccose in appearance. These masses as they grow, exude numerous small drops of a colorless watery liquid, after which they change to cream color, which gradually passes to a dirty yellow, the developing sclerotial membrane losing their floccose character. Their color changes to a greenish black, afterward to almost pure black as they mature.

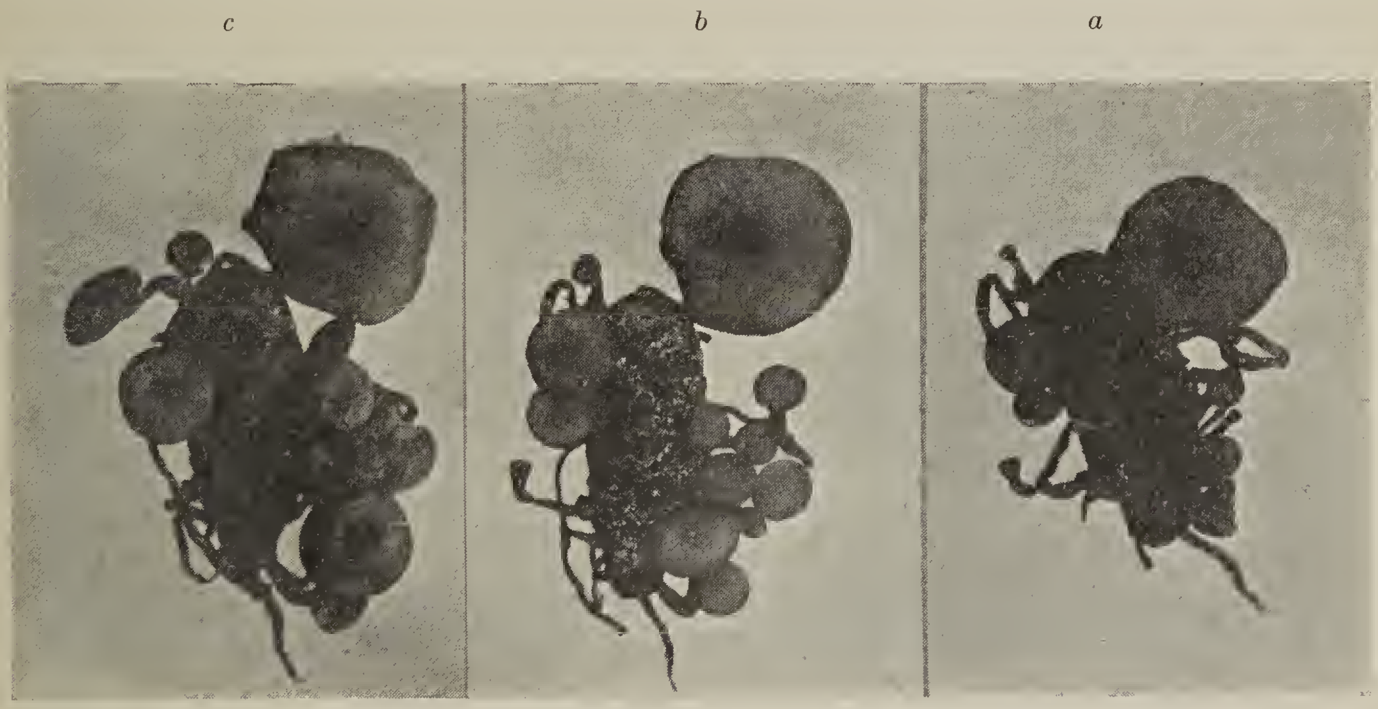


FIG. 18.—Sclcrotium with disks. *a*, Photographed January 10; *b*, January 12; *c*, January 14. Note the recurved edges of the largest disk.

To secure *germination of the sclerotia*, they were placed in moist sand in flower pots which were kept standing in a pan of water thus keeping the sand wet by capillarity. After about two months the sclerotia began to send out minute yellowish-brown bud-like protuberances. These rapidly elongated to form a filament which as soon as it reached above the soil and into the light, began to expand, at first to an urn-shape and then gradually flattening into a broad, flat disk, Fig. 18. In some cases the disk became recurved with age, Fig. 17c, having the appearance of a very minute yellowish brown umbrella, the ascophore. From 3 to 35 ascophores were produced from each sclerotium.

The Ascophore.—The *Ascophore* may be regarded as composed of two portions, the stalk or stipe, and the disk, though no sharp line of demarkation can be drawn between these parts. As many as thirty-five stipes have been noted from a single sclerotium, but usually there are not more than eight or ten. There are no particular points upon the sclerotium from which they arise, but in case the sclerotium lies upon the surface of the ground, they usually spring from the sides of it nearest to the soil. Their length depends upon the depth of the sclerotium in the soil. If the sclerotium is upon the soil surface, the stipe is just long enough to allow the disk to expand. When the sclerotium is buried the stipe becomes a sufficient length to reach the surface, sometimes attaining a length of 3 to 5 cm. In thickness the stipes vary from about 0.5 to 1.2 mm. The color of the shorter stipes is almost universally brownish yellow, but the longer ones while brownish yellow just below the disk are dark brown to almost black at the sclerotial end.

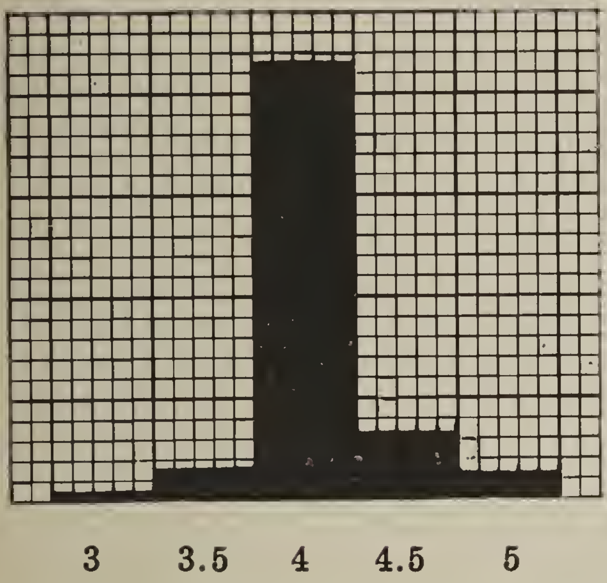
In cross section the stipe is seen to be hollow and to possess an outer cortical region composed of two or three irregular layers of black thick-walled cells, encasing a tissue of parenchymatous appearance. In longitudinal section, cells of the outer cortical layers appear about three times as long as wide, while the rest of the tissue appears as a mass of ordinary mycelial threads with rather more than the usual number of septa.

The disk is borne upon the end of the stipe. It is at first very small and deeply cup shaped. This cup gradually expands at the rate of one-half to 1 mm. per day and forms the flat or concave circular disk, which sometimes attains a diameter of 16 mm. It is composed of two distinct parts, the *stroma* and the *hymenium.* The stroma or basal part consists of a mass of closely interwoven hyphæ with an outer cortical parenchymatous layer two or three cells thick which forms the under surface of the disk. The stroma supports the hymenium composed of *asci* (Fig. 6) and *sterile* hyphæ lying between them, the paraphyses (Fig. 6). The asci are cylindrical with a gradually narrowing base. They measure about 82 x 2 mu and bear 8 spores in their distal half. The asci are very numerous, there being about 30,000 in a single disk of usual size. Between the asci and more numerous than the asci are the very fine thread-like paraphyses which are slightly longer than the asci, and not more than one-third as thick. The paraphyses do not differ materially from the ordinary hyphæ of the mycellium.

The spores found in the asci are hyaline, oblong, elliptical with somewhat pointed ends, and when mature bear two vacuoles. They measure 5.8 x 8.7-11.6 mu.

In a single disk there are about thirty-one million spores; in a single sclerotium of average size about three hundred and ten million spores. Allowing a fair number of sclerotia to each diseased lettuce plant it is seen that it can produce as many as five billion spores.

When mature the spores are ejected forcibly from the asci. Great numbers of them ripen at the same time and the slightest change in environmental conditions, as a slight draught produced by the breath causes myriads of them to be thrown into the air often to a distance of 0.5 to 1.0 meter, their great number rendering them visible as a steam-like cloud which, caught by air currents, can often be followed by the eye to a distance of several meters.



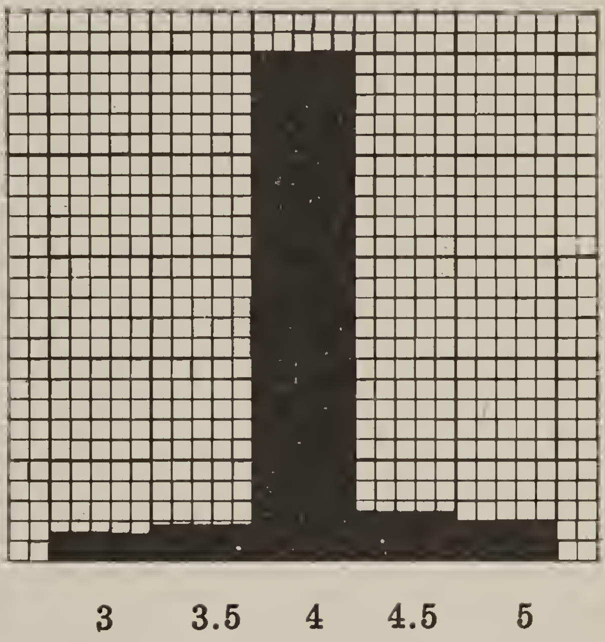
$M = 4.0880 \pm 0.0166$

$\sigma = 0.2930 \pm 0.0117$

C. V. $= 7.168 \pm 0.290$

$n = 142$

FIG. 19.—*Sclerotinia libertiana* Fckl. Polygon of ascospores from middle-aged disk.



$M = 4.0393 \pm 0.0214$

$\sigma = 0.3743 \pm 0.0151$

C. V. $= 9.267 \pm 0.380$

$n = 165$

FIG. 20.—*Sclerotinia libertiana* Fckl. Polygon of spores from young disk.

Several hundred measurements were made from disks of various ages to determine the normal variation in sizes of ascospores with the results shown in Figs. 19 and 20.

It is seen that the spores are remarkably constant in size and that the age of the disk (Figs. 19 and 20) from which they are taken has no material effect upon their measurements.

The spores as discharged from the asci are ready, if they fall in favorable places, to germinate at once. In germination they first enlarge somewhat and soon a protuberance can be seen at some spot on the surface. This protuberance increases in length, becomes septate and constitutes the germ tube, the beginning of the mycelium.

THE SPECIES OF THE FUNGUS.

The species under consideration has by recent writers been regarded as *Sclerotinia libertiana* Fuckel which is thus described[19]:

"Sparsa, stipitata, nuda, pallida, cyathoidea, 4-8 m.m. lat.; stipite tenui subflexuoso, *Sclerotio* tuberiformi, nigro innato, plus minus elongato, sæpissime 3 cm. long; ascis cylindraceis, 130-135 x 8-10, apice jodo dilute coerulescentibus; sporidiis monostichis, ellipsoideis, vulgo minute guttulatis, 9-13 x 4-6.5; paraphysibus parcis, clavulatis."

Comparison of the fungus under discussion with the description of eleven species which most nearly agreed with it showed that all failed to agree with it in some important point except *Sclerotinia libertiana* and *S. kauffmanniana;* the latter considered a synonym of *S. libertiana* by some authors.

PHYSIOLOGY.

THE MYCELIUM.

Media.—This fungus lends itself readily to culture upon either artificial or live media. Its growth upon various media was first studied to ascertain the best medium to employ in experimental work and the best medium for stock cultures.

Upon lettuce leaves in culture dishes a great mass of mycelium of loose cottony consistence, which very quickly collapsed on exposure to the air, was produced and very few sclerotia were formed.

In lettuce broth a vigorous mycelium developed.

Lettuce agar gave only a very thin surface layer of mycelium, and very few sclerotia.

Four-per-cent. pea-agar gave about the same growth as did lettuce agar.

Sterilized corn meal, wet with apple juice, gave excellent growth and produced by far the greatest number of sclerotia. The mycelium while mainly coating the surface of this medium was very compact and dense. Corn meal wet with lettuce broth was equally satisfactory. In all of the foregoing media a much more abundant mycelium was formed if the medium was slightly acid.

The corn-meal-apple-juice mixture was adopted for the study of the development of sclerotia and as a medium on which to maintain stock cultures. Lettuce broth was used to grow mycelium for tests regarding the effects of soluble chemicals, since the mycelium developed well, and uniformly, in this medium and was readily wetted by the solutions employed in the experiments which was not the case when media leading to the development of a profuse aereal mycelium were employed.

Experiment 9, Inoculated 11-30-1906. To determine the *temperature relations* of the fungus.

Sclerotinia libertiana was grown upon lettuce agar, acidity +.55 Fuller's scale, and upon lettuce leaves at cool, room temperature, incubator temperature and in an open shaded window, all in ordinary diffused light except the culture in the incubator room which were in the dark. The results are shown in the following table.

TABLE I.—SHOWING RELATION OF TEMPERATURE TO GROWTH.

FIGURES INDICATE TOTAL GROWTH RECORDED AS MILLIMETERS.

Medium	Condition	Growth										
		December										
		1st	3d	4th	5th	6th	7th	8th	10th	11th	12th	13th
Agar	Window shaded	1	5	5	5	10	15	17	23	30	35	37
Lettuce leaf	Window shaded	0	0	5	5	25	30	40	60	60	70	70
Agar	Cool room	4	13	20	40	40	47	53	70	70	78	------
Lettuce leaf	Cool room	20	20	20	35	50	------	------	------	------	------	------
Agar	Incubator room	4	6	6	6	6	6	6	6	6	6	------
Lettuce leaf	Incubator room	4	4	4	------	------	------	------	------	------	------	------

It is clearly evident that the incubator temperature (approximately 37 1-2 degrees) was unfavorable to the growth of the fungus. Growth stopped entirely after the first few millimeters and was not resumed, nor were any sclerotia formed.

The room temperature, which was considerably warmer than the window temperature of December, was more favorable to growth, resulting in complete occupancy of the plate in 9 to 11 days. While growth was slower at the colder outdoor temperature it still continued vigorously and normally, leading eventually to complete occupancy of the plate. Sclerotia were formed upon the lettuce leaf at both room and outdoor temperatures.

Experiment 48, March 12, 1908. To determine more accurately the optimum growth temperature in agar, cultures were made in this medium and placed in an optimum temperature apparatus.*

The work was done in quadruplicate and care was taken to have all cultures as nearly as possible parallel as to moisture, quantity and quality of inoculum and all factors except temperature. The results are expressed in table II.

It is seen that growth was markedly less in the two warmer compartments (29 and 36-39 degrees). No growth at all occurred in the warmest compartment and no sclerotia formed in either of these compartments. In the compartment of lowest temperature (13-18 degrees) growth was also much retarded but it still continued, leading to complete occupancy of the plate in twelve days and to sclerotial formation in thirteen days.

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*An incubator with six compartments, giving a considerable range of temperatures.

TABLE II—SHOWING RELATION OF TEMPERATURE AND GROWTH.

	Temperature—Compartment Number								‡ Growth—Compartment Number					
	1		2	3	4	5	6		1	2	3	4	5	6
Date	Max.	Min.					Max.	Min.						
3-14-08	13	16	21	24	26	29	36	39	0	4	5	3	4	0
3-16-08	13	21	23	25	27	29	36	39	10-15	16-21	20	17	16	0
3-17-08	13	23	21	24	26	29	36	39	0-10	13-15	13	10-15	7	0
3-18-08	13	17	21	24	26	29	36	39	5-10	13-16	14-17	0- 5	8	0
3-19-08	14	17	21	24	26	29	36	39	7-27	13-21	5- 9	2	5	0
3-20-08	13	16	21	24	26	29	36	39	8-25	F*	F	8	5	0
3-21-08	14	17	21	24	26	29	36	39	5-10	F	F	10	5	0
3-23-08	13	18	21	24	26	29	36	39	10	F	F	10	10	0
3-24-08	13	16	21	24	26	29	36	39	10-25	F	F	F	0	0
3-25-08	12	18	21	24	26	29	37	39	F	S†	S	S	0	0
3-26-08	13	18	21	24	26	29	36	39	S	S	S	S	0	0
Average number of sclerotia per culture									1	2	2	1.8	0	0

* F indicates date upon which mycelium filled plate.

† S indicates that sclerotia were forming.

‡ Growth for each day is recorded in millimeters. In compartments 1 and 6 maximum and minimum thermometers were used.

Of the four compartments of intermediate temperature the two cooler (21 and 24 degrees) were more favorable than the two warmer (26 and 29 degrees). In the two former complete occupancy of the plate by the mycelium occurred in six days while the others required four days more.

From these tests we may conclude that this fungus can not continue to grow long at a temperature of 29 degrees or higher; that at a temperature as low as 13-18 degrees or as high as 26 degrees growth proceeds normally but not so rapidly as at the optimum temperature; which lies between 21 and 24 degrees.

Experiment 13. To determine *longevity of mycelium* in agar in petri dishes. A ten-per-cent. lettuce agar was employed, acidity +.55 Fuller's scale. Tests were made in the laboratory, the results of which appear in table III.

From this table it is seen that the mycelium remained alive as long as forty-eight days, but in no case did it live beyond the fifty-fifth day. The length of life after the agar was dry in the petri dish varied from five to ten days.

Experiment 12. To determine the *effects of various nutrients* upon growth. Sclerotinia was grown in petri dishes upon plain agar with various nutrients added. 10 c.c. of medium was used in each dish. The petri dishes were inoculated 12-11-1906.

TABLE III.—SHOWING LONGEVITY OF MYCELIUM IN AGAR IN PETRI DISHES.

Plate No.	Date of Inoc.	Date of Filling Plate	Date of Drying	tested	alive	tested	alive	tested	alive	tested	alive	tested	alive	tested	alive
1	5–15–09	5–21	6–20	6–1	Yes	6–14	Yes	6–23	Yes	6–30	Yes	7– 7	No	------	------
2	5–15–09	5–21	6–20	6–1	"	6– 8	"	6–14	"	6–23	"	6–30	Yes	7– 7	No
3	5–15–09	5–23	6–22	6–1	"	6– 8	"	6–14	"	6–23	"	6–30	"	7– 7	No
1	6–14–09	6–18	7–18	6–18	"	7– 7	"	7–14	"	7–23	"	8– 3	No	------	------
2	6–14–09	6–18	7–18	6–18	"	7– 7	"	7–14	"	7–23	"	8– 3	"	------	------
3	6–14–09	6–18	7–18	6–18	"	7– 7	"	7–14	"	7–23	"	8– 3	"	------	------
4	6–14–09	6–18	7–18	6–18	"	7– 7	"	7–14	"	7–23	"	8– 3	"	------	------
1	9–23–09	9–27	10–28	9–30	"	10–14	"	10–28	"	11– 7	"	11–10	"	------	------
2	9–23–09	9–27	10–28	9–30	"	10–14	"	10–28	"	11– 3	"	11–10	"	------	------
3	9–23–09	9–27	10–28	9–30	"	10–14	"	10–28	"	11– 3	"	11–10	"	------	------

As might have been expected growth was very slow in plain agar, while 5 per cent. glucose, and 1 per cent. starch proved most favorable. Lettuce agar was much superior to plain agar but far less nutritious than starch or glucose agars.

The deficiency of the peptone and lactose agars is striking, seeming to emphasize the lack of need of rich nitrogenous foods for this fungus and to show the superior value of glucose over lactose as a source of carbon. There was no reddening of the litmus lactose agar by the mycelium.

Sclerotia were formed on all of these media except the peptone and the litmus lactose agar.

TABLE IV.—SHOWING EFFECTS OF VARIOUS NUTRIENTS UPON GROWTH.

GROWTH IS RECORDED IN MILLIMETERS.

	Medium	Days									
		1	2	3	4	5	6	7	8	9	10
1	Plain agar	5	9	14	20	23	25	30	30	39	---
2	Plain agar	2	2	12	16	25	32	35	36	43	---
3	Plain agar+1 per cent glucose	3	11	25	28	34	38	42	----	----	---
4	Plain agar+1 per cent glucose	1	4	10	10	15	24	26	----	----	---
5	Plain agar+5 per cent glucose	2	8	40	65	----	----	----	----	----	---
6	Plain agar+5 per cent glucose	3	25	75	Fills Plate	----	----	----	----	----	---
7	Plain agar +1 per cent peptone	2	5	10	10	12	12	15	----	----	---
9	Plain agar+Litmus lactose	2	10	20	24	26	28	----	----	----	---
10	1 per cent starch agar	3	13	30	40	45	50	60	----	----	---
11	1 per cent starch agar	2	8	25	42	----	50	58	----	----	---
12	Lettuce agar	4	13	20	40	47	53	70	----	----	---
13	Lettuce agar	4	8	14	22	32	42	48	----	----	---

Experiment 8. To determine the *influence of acidity or alkalinity* of the medium. On December 8, 1906, the fungus was inoculated and grown in lettuce agar of various degrees of acidity and alkalinity as is shown in the table following.

TABLE V—SHOWING RELATION OF ACIDITY TO GROWTH.

TOTAL GROWTH IS RECORDED IN MILLIMETERS.

Drops of Normal HcL or NaOH	Fuller's Scale	Day									
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
+20											
+15											
+10	+40.55	0	0	0	0	0	0	0	0	0	0
+5	+20.55	0	2	3	5	7	12	16	16	18	18
0	+ .55	6	14	28	36	41	67	75	83	83	83
—5	—19.45	0	10	0	0	0	0	0	0	0	0
—10	—39.45	0	0	0	0	0	0	0	0	0	0
—15	—59.45	0	0	0	0	0	0	0	0	0	0
—20	—79.45	0	0	0	0	0	0	0	0	0	0
Date	December	11	12	13	14	15	17	18	19	20	21

It is seen that growth was inhibited by + 40.55 and — 19.45 of Fuller's scale. At + 20.55 growth was slow. At + 0.55 occurred the maximum growth.

Experiment 15. To determine the *toxicity of various fungicides* acting directly upon the mycelium.

Sclerotinia was grown in glass capsules in lettuce broth until a vigorous mycelium was obtained. The broth was then poured off and the mycelium was washed free of any remaining broth by allowing about one litre of sterile water to pass slowly through it by means of a small siphon. A small portion of the mycelium, the quantity as nearly equal as possible in all cases, was then transferred to the poison, the effect of which was to be tested. After ten minutes, one-third of this mycelium was removed, rinsed in several changes of sterile, distilled water and placed in tubes of sterile lettuce agar to test its viability. Other portions of the mycelium were similarly removed at the end of an hour and of twenty-four hours. The temperature of the poisons when used was approximately 21 degrees. The results are shown in table VI.

This experiment shows the inefficiency of a ten minute's application of such fungicides as ammoniacal-copper-carbonate, strong and weak Bordeaux, formalin 1 ounce to 1 gallon, and 1 ounce to 2 gallons, saturated lime water, and potassium permanganate 1 ounce to 10 gallons, though each of the above is fatal if applied for one hour.

TABLE VI.—SHOWING TOXICITY OF VARIOUS FUNGICIDES.

+ = viable; — = not viable.

Fungicide	Strength	10 Min.	1 Hr.	24 Hrs.
Ammoniacal Copper Carbonate	Copper Carbonate, 6 ozs.; Ammonia, 3 pts.; H_2O 50 gals.	+	—	—
Bordeaux Mixture	5 lbs. $CuSO_4$, 5 lbs. Lime, 50 gals. H_2O	+	—	—
Bordeaux Mixture	2 lbs. $CuSO_4$, 2 lbs. Lime, 50 gals. H_2O	+	—	—
Potassium Sulphide	1 oz. Potassium Sulphide, 1 gal. H_2O	+	+	+
Potassium Sulphide	1 oz. Potassium Sulphide, 3 gals. H_2O	+	+	+
Lead Acetate	1 oz. Lead Acetate, 1 gal. H_2O	+	+	+
Lead Acetate	4 ozs. Lead Acetate, 1 gal. H_2O	+	+	+
Potassium Permanganate	1 oz. Potassium Permanganate, 1 gals. H_2O.	—	—	—
Potassium Permanganate	1 oz. Potassium Permanganate, 3 gals. H_2O.	—	—	—
Potassium Permanganate	1 oz. Potassium Permanganate, 5 gals. H_2O.	—	—	—
Potassium Permanganate	1 oz. Potassium Permanganate, 7 gals. H_2O.	—	—	—
Potassium Permanganate	1 oz. Potassium Permanganate, 10 gals. H_2O	+	—	—
Formalin	1 oz. Formalin (40 %), 1 gal. H_2O	+	—	—
Formalin	1 oz. Formalin (40 %), 2 gals. H_2O	+	—	—
Formalin	1 oz. Formalin (40 %), 3 gals. H_2O	+	+	+
Sodium Benzoate	1 oz. Sodium Benzoate, 1 gal. H_2O	+	+	+
Sodium Benzoate	1 oz. Sodium Benzotte, 2 gals. H_2O	+	+	+
Sodium Benzoate	1 oz. Sodium Benzoate, 5 gals. H_2O	+	+	+
Sodium Benzoate-Bordeaux	½ lb. Sodium Benzoate, 1 lb. $CuSO_4$, 1 lb. Lime, 50 gals. H_2O	—	—	—
Iron Sulphate	15 %	+	+	+
Lime Water	Saturated	+	—	—
Lime Paste		—	—	—

Potassium sulphide, 1 ounce to 3 gallons and 1 ounce to 1 gallon, lead acetate 1 ounce to 1 gallon and 4 ounces to 1 gallon, formalin 1 ounce to 3 gallons, sodium benzoate 1 ounce to 1 gallon, 1 ounce to 2 gallons, 1 ounce to 5 gallons, and iron sulphate were not fatal even with a twenty-four-hour application.

Potassium permanganate 1 ounce to 1 gallon, 1 ounce to 3 gallons, 1 ounce to 5 gallons, and 1 ounce to 7 gallons, lime paste and sodium-benzoate-Bordeaux (one-half pound sodium benzoate, 1 pound copper sulphate, 1 pound lime to 50 gallons) were fatal even with the shortest period tested.

The inefficiency in these comparatively strong solutions of potassium sulphide and of formalin indicates considerable vigor and resistance on the part of the fungus.

Experiment 19. Copper sulphate was tested following the method of the last experiment, using strengths varying from N/100 to N/6400 and varying the time from 5 to 105 minutes. With the three weaker strengths, tests were made continuing to twenty-four hours. The tests were made with the solutions at a temperature of 17 degrees. The results are shown in the following table:

TABLE VII.—SHOWING TOXICITY OF COPPER SULPHATE.

o = Not viable; + = Viable.

Strength of Solution.	TIME IN HOURS.																							
	1/12	1/6	1/4	1/3	5/12	1/2	7/12	2/3	3/4	5/6	11/12	1	1 1/12	1 1/6	1 1/4	1 1/3	1 5/12	1 1/2	1 7/12	1 2/3	1 3/4	4	8	24
$\frac{n}{100}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	o	o	o	o	o	o	o
$\frac{n}{200}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	o	o	o	o	o	o	o
$\frac{n}{400}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	o	o
$\frac{n}{800}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	o	o	o
$\frac{n}{1600}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
$\frac{n}{3200}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
$\frac{n}{6400}$	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

In all cases here copper sulphate failed to cause death of the mycelium, until the mycelium had been subjected to the solution for 80 minutes. It then caused death with the two stronger solutions, N/100 and N/200. N/400 and N/800 did not cause death till the expiration of 105 minutes, and even 24 hours soaking in the three weaker solutions, N/1600, N/3200 and N/6400, failed to kill the fungus.

In conditions unfavorable to mycelial growth, for example upon plain agar, or agar otherwise deficient in nutrients the gonidia were produced in abundance. Their production also occurred in the midst of dense masses of mycelium in late periods, apparently due to the unfavorable effects of lack of nutrients or to the development of inhibiting products. They were also formed abundantly from the germ tubes of ascospores in drop cultures in sterile water within a few days after the cultures were made. Here no nutriment was accessible except that present in the spore itself.

Careful count was made of the number of sclerotia upon various parts of affected lettuce plants. The results are given in Table IX.

These plants were naturally infected in the lettuce beds. It is seen that the greater number of sclerotia was formed in the axils of the leaves around the stem. Those formed in the ground on the root were produced only after the root had begun to decay. No plants that were examined, in which the roots had not begun to decay, showed signs of sclerotia below ground and in very few instances was there any external sign of the fungus in the parts below ground.

If half of a bed of the usual size, 9 x 100 feet, bearing 2,000 plants, be diseased (this is not an uncommon percentage), it is seen that there may be formed as many as 17,100 sclerotia per bed. It is quite certain that this estimate does not fully represent the actual number formed under conditions of badly infected beds.

TABLE VIII.—SHOWING DISTRIBUTION OF SCLEROTIA IN THE PLANT.

Plant No.	On Ground	In Axils of Leaves	Among Leaves	On Ground in Root	Total
1		9	2	1	12
2		9		2	11
3		9			9
4	1	14	8	10	33
5		9	1	4	14
6		13	2	4	19
7		8	14	4	26
8		23	1		24
9		10		4	14
10		9			9
Total	1	113	28	29	171
Average	1	11.3	2.8	2.9	17.1

Sclerotia can be grown upon a great variety of media but upon some media they do not develop in any large quantity. They were formed upon the surface of the lettuce broth cultures after the mycelium had grown to a considerable extent, thus forming a support for them; but sclerotia have never been seen to form within the liquid medium itself and plants brought into the laboratory and kept in culture dishes where they became very wet did not form as many sclerotia as those placed upon soil in the greenhouse where the plants were less wet.

In a test of plain agar, plain agar plus 1 per cent. glucose, plain agar plus 5 per cent. glucose, plain agar plus 1 per cent. peptone, plain agar plus litmus-lactose, plain agar plus 1 per cent. starch and lettuce agar, it was seen that sclerotia formed in all the media except those which contained peptone or litmus-lactose. In a test of temperature relations no sclerotia developed in the higher temperatures, above twenty-six degrees C.; nor at the lower temperatures, below eight degrees C. The formation of sclerotia is inhibited by these extremes before the growth of the mycelium is stopped.

Two cultures of Sclerotinia upon the corn meal saturated with apple juice, in 20 cm. culture dishes, were inoculated January 17, 1907, and the first mature sclerotia were picked from these cultures on January 28th, 11 days from inoculation.

From these cultures full size, black sclerotia were taken every alternate day until February 8th, then every third day until February 17th; a period in all of one month from the date of inoculation. During this time one of the cultures produced 523 sclerotia and the other 397 or a total of 920 for the two cultures. The following table shows the number of sclerotia taken on each date.

TABLE IX.—SHOWING SCLEROTIA PRODUCTION IN CULTURES.

Date	Jan. 28, '07	Jan. 30, '07	Feb. 2, '07	Feb. 4, '07	Feb. 6, '07	Feb. 8, '07	Feb. 11, '07	Feb. 14, '07	Feb. 17, '07	Total
Sclerotia taken from Culture, A	52	39	105	10	39	75	67	65	71	523
Sclerotia taken from Culture, B	52	89	39	75	10	41	29	26	36	397
Total	104	128	144	85	49	116	96	91	107	920

The formation of sclerotia seems dependent upon the attainment of a certain mycelial density. Thus upon a rich medium, as corn meal, continued branching accompanied by radial enlargement of the colony soon leads to mycelial crowding. A quite regular ring or zone of sclerotia results, Fig. 21. Again radial expansion begins and after a certain interval another ring of sclerotia is produced. This alternation is repeated indefinitely.

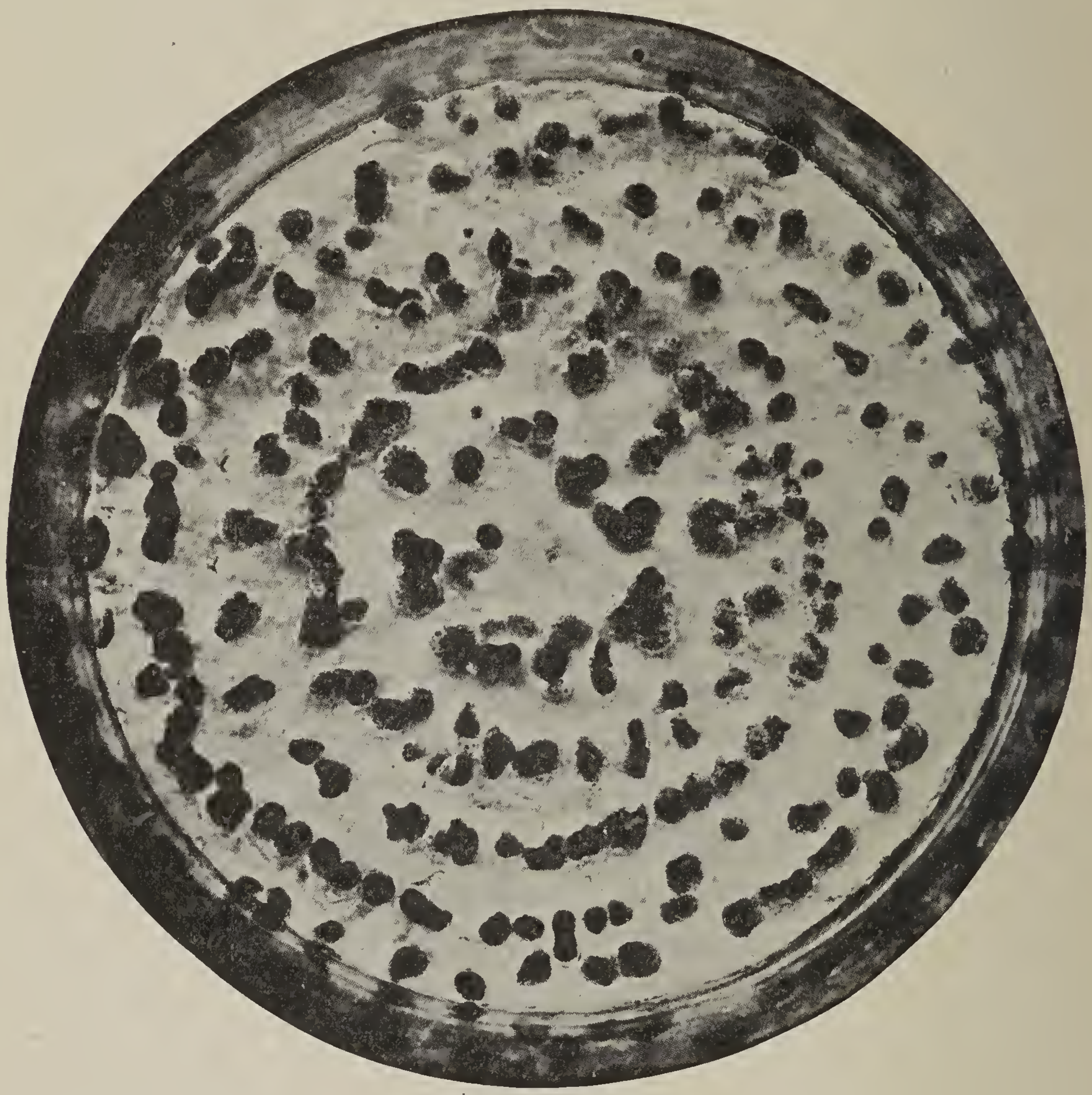

FIG. 21.—Sclerotia produced in culture upon corn meal wetted with apple broth, showing concentric rings of sclerotia around the central point of inoculation.

When several colonies are so located that they meet mycelial crowding must occur at the points of contact. Here, too, sclerotia develop in abundance, Fig. 22. Attention has been called elsewhere,[18] to the importance of mycelial crowding as a stimulus.

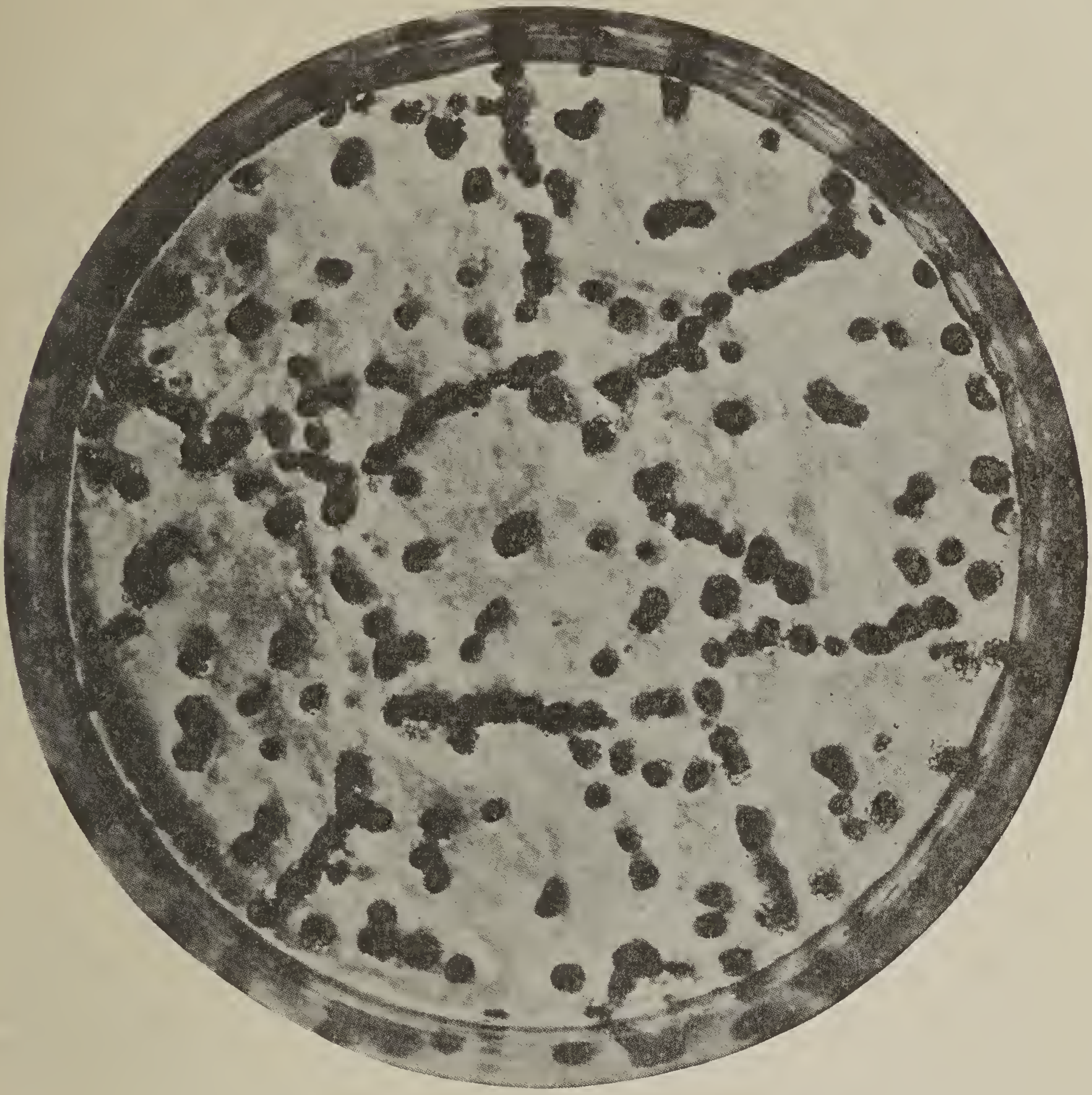

FIG. 22.—Sclerotia produced in culture upon corn meal wetted with apple broth, showing rows of sclerotia where colonies met.

To determine the length of time necessary for sclerotia to mature, for germination, a large number of sclerotia was taken from corn meal cultures and air dried for a few days. They were then planted in pots of sterilized soil at periods of a week apart. At each of these plantings old sclerotia, that were known to be mature, were also planted as controls. All of these grew, even those which were picked and merely air dried for a day or so showing as vigorous germination as did the old sclerotia. It thus appears that sclerotia are mature as soon as formed and are ready to germinate at once if favorable conditions obtain.

Attempts were made to determine the length of life of sclerotia under laboratory conditions and lettuce bed conditions. In the laboratory sclerotia were stored in ordinary room temperature, one lot in the dark all the time, another lot alternately in the light and dark of day and night, a third lot was kept wet all the time. Three similar sets were kept in the incubator room (temperature 37 degrees). At the end of 11 months those kept wet were found to have all decayed. Of those kept dry a little more than one-third (24 out of 60) produced ascophores normally. In an out-door test a large quantity of sclerotia was collected, placed in the lettuce beds at one-half inch depth in March. These were examined twice during the early part of the summer and were all sound. The third examination was made August 11, 1909 (five months and eleven days after placing them in the soil) and it was found that they had all decayed and the only thing left was the hard, black, parenchymatous, shell-like outside coverings and a very few of the thread-like stumps of stipes, abortive attempts at germination. While the longevity of the sclerotia under conditions most favorable to them has not yet been determined, it is evident that *under usual conditions their number must be largely reduced by decay.*

Germination of Sclerotia.

To determine the conditions most favorable to their germination sclerotia were placed:

(1) In ordinary three-inch flower pots filled with soil and these placed in a shallow dish of water. The pots were covered with strips of bibulous paper with the ends bent down into the water. The sclerotia were pressed into the soil until they were just level with the surface.

(2) Similar pots were prepared in the same way and placed in the incubator room and covered with bell jars instead of paper.

(3) Pots were placed outdoors on the north side of the building in a shady and cool location.

(4) Pots prepared as in the first case but not covered with paper were kept in the laboratory taking precaution only to keep water in the dish in which they were placed.

Ascophores were produced in all cases except under the incubator room conditions in which case no ascophores were formed until the pots were removed to the laboratory. The fourth method was found to be the most satisfactory and convenient for laboratory use.

Apothecia produced under unequal illumination are strongly positively phototropic turning their disk faces toward the source of light.

An experiment was made to determine the maximum depth in the soil at which sclerotia would germinate and produce apothecia. Three six-inch flower pots were filled with soil and each pot was divided into two compartments by glass partitions, sclerotia were then planted at depths of 1-2, 1, 1 1-2, 2, 2 1-2, and 3 inches. No apothecia were formed from sclerotia placed at a greater depth than 1 1-2 inches and by far the largest number of apothecia was formed from sclerotia at the minimum of the above depths.

To study the effect of stirring the soil over the sclerotia when in conditions favorable to their germination sclerotia were planted in soil in a two-foot flat in the laboratory and kept properly watered. Half of the flat was left intact and undisturbed. In the other half the soil surface was stirred or hoed every two weeks. In the undisturbed half apothecia were formed normally. More than 10 were counted at 25 days after planting. In the half of the flat in (Fig. 23) which the soil was stirred, no apothecia at all were formed even after 60 days' test.

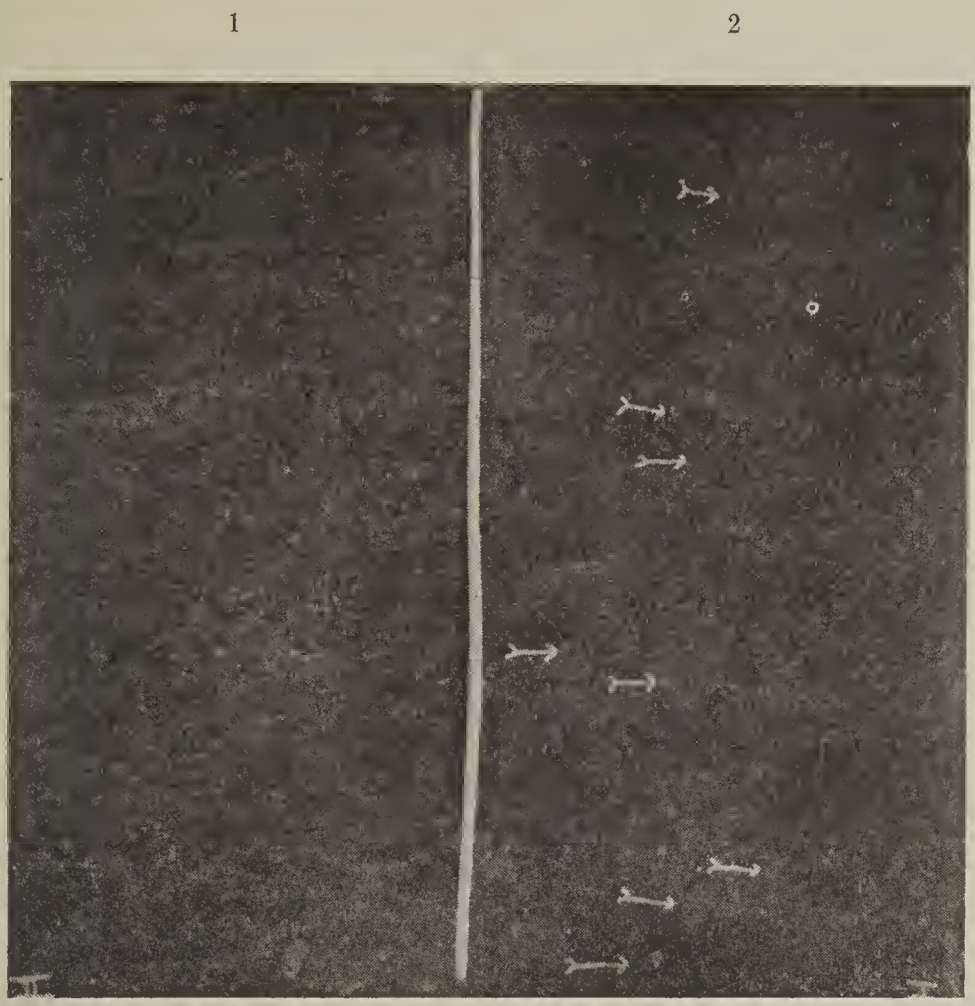

FIG. 23.—Flat showing the effect of stirring the soil upon the formation of apothecia. 1, Not stirred. 2, stirred every two weeks.

THE ASCOPHORE.

To determine the effect of mutilation of the ascophore, sclerotia were germinated and the stipes, as soon as they began to expand, were cut off at various distances from the apex. It was found that these stipes ceased to develop, except when they were cut just at the base of the forming disk. In such cases, however, new disks began to develop at once and sometimes two or three appeared upon the end of one mutilated stipe, Fig. 24.

To ascertain the effect of light or darkness upon the formation of the ascophore a flat was divided into four sections and planted December 14, 1906, with sclerotia. The first section was left uncovered, the second was covered with unprinted newspaper, the third with light weight manilla paper and the fourth with heavy weight manilla paper. Examination on February 5, 1907, showed that disks were fully formed upon section one, uncovered, though no disks showed in any of the other sections (Fig. 25). On February 27 the paper was all removed, and on March 11 very numerous disks were first observed on these newly uncovered sections. The time which elapsed between the removal of the paper and the appearance of the disks was considerably less than is usually taken to produce ascophores and it is probable that the presence of the paper simply inhibited the formation of the disks, not of the stipe of the ascophore. Light is evidently the stimulus which causes the tip of the sprouts which come from the sclerotium to stop growing in length and to expand into the disks and the presence of the paper covering was probably sufficient to exclude the light and thus to prevent this reaction.

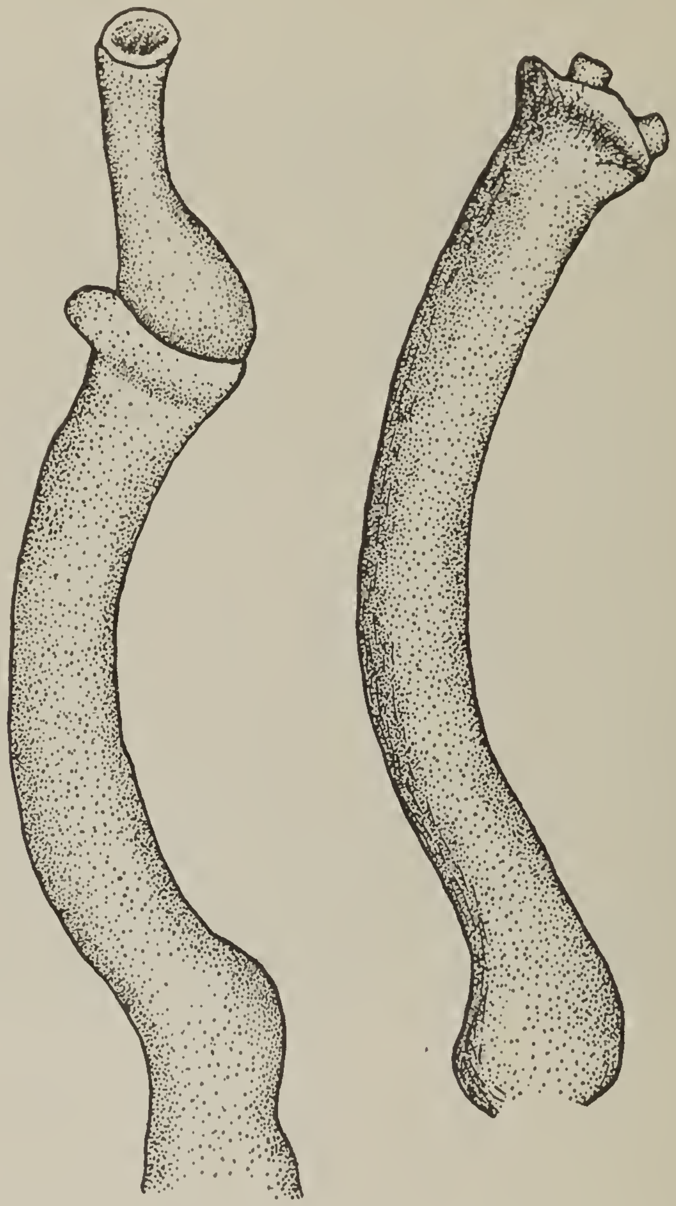

FIG. 24.—Ascophores, showing new disk formation after mutilation.

As shown on page 118 heat or cold beyond certain limits retards or inhibits the formation of ascophores. The maximum temperature for ascophore formation seems to be about 8 to 25 degrees C.

THE ASCOSPORES.

The ascospores, as has frequently been noted, are discharged quite forcibly into the air when mature. To observe this phenomenon sclerotia-bearing disks were grown in flower pots and covered with plates of glass, or kept in tea cups covered with damp cloth. Upon the removal of the covering clouds of spores were forcibly ejected and could be followed by the eye for a distance of several feet. Currents of air caused by any one passing rapidly by ripe disks in open pots caused the ejection of spores. Spores for study were readily secured at any time by placing a cover glass over a ripe disk, then breathing lightly upon it, resulting in an immediate and copious discharge of spores upon the cover glass.

To determine the per cent. of germination of ascospores and the toxic effect of copper sulphate, Bordeaux-mixture-filtrate and other substances hanging drop cultures were made in lettuce broth, in distilled water and tap water, also in various toxic substances. The tests were made by catching spores upon cover glasses by the method described above and preparing hanging drops with these, using the solution to be tested. The percentage of germination was read when the spores ceased to germinate.

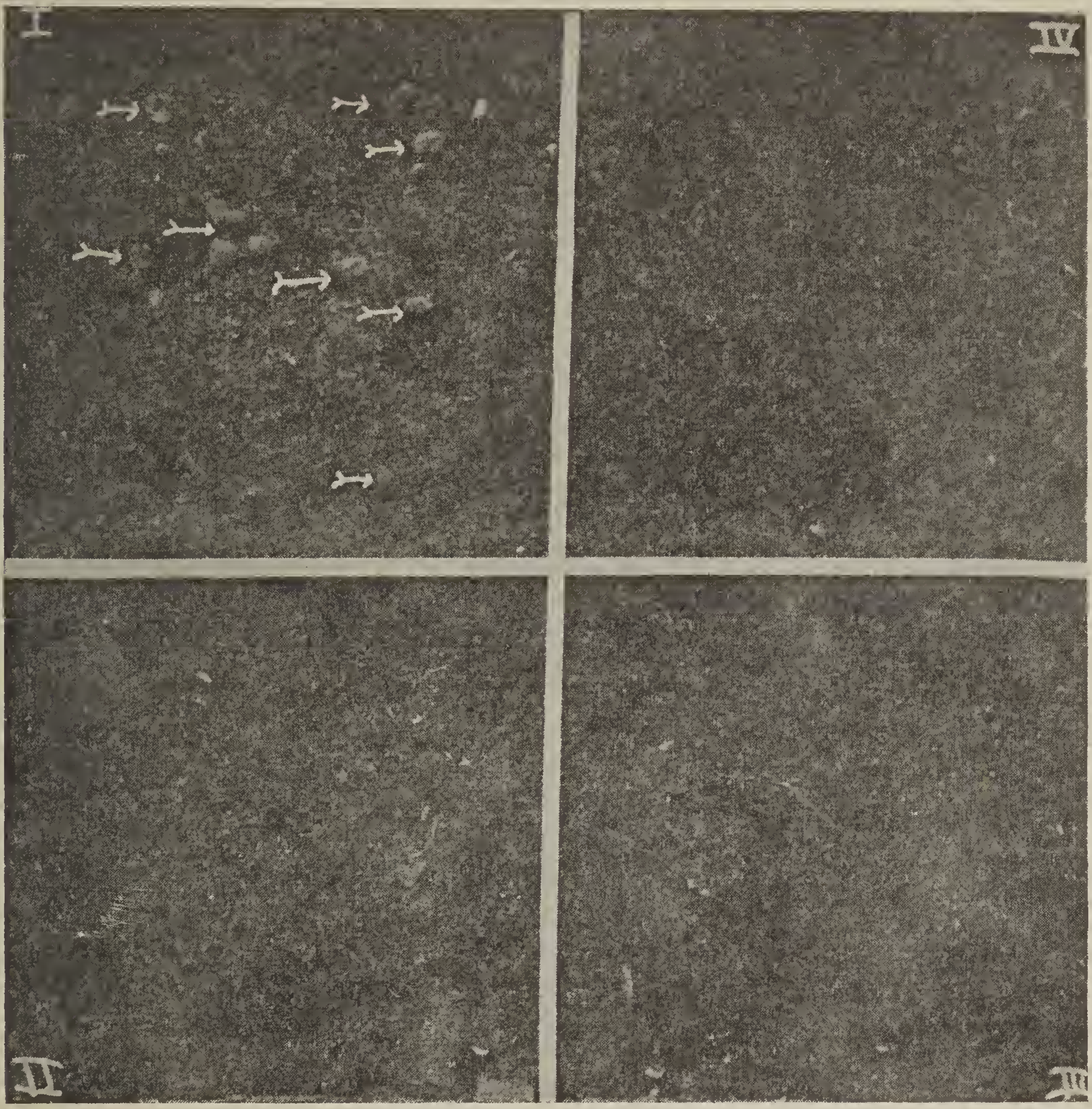

Fig. 25.—Flat showing effects of different coverings upon the development of apothecia. I, Not covered; II, covered with heavy manila paper; III, covered with light manila paper; IV, covered with unprinted newspaper.

Bordeaux filtrate No. 1 was made by merely filtering freshly prepared Bordeaux Mixture. The residue remaining upon the filter paper was then allowed to dry and remain thus one week. It was then washed with the least possible quantity of water and this wash water filtering through was tested as Bordeauz filtrate No. 2.

The result of these tests are shown in the following table:

TABLE X.—SHOWING EFFECT OF VARIOUS SUBSTANCES UPON SPORE GERMINATION.

Germination, Per Cent	Medium used.
68	Water distilled from Bichromate of Potash.
80	Distilled Water with Lampblack added, then filtered.
85	Ordinary Distilled Water.
92	Tap Water.
100	Lettuce Broth.
0	Copper Sulphate solution $\frac{n}{100}$
0	Copper Sulphate solution $\frac{n}{200}$
0	Copper sulphate solution $\frac{n}{800}$
10	Copper Sulphate solution $\frac{n}{1600}$
20	Copper Sulphate solution $\frac{n}{3200}$
50	Copper Sulphate solution $\frac{n}{6400}$
0	Bordeaux Mixture, Filtrate No. 1.
100	Bordeaux Mixture, Filtrate No. 2.

It is seen here that germination was more in ordinary distilled water than in the supposedly non-toxic water (U. S. Bureau of Soils) and that still higher germination was attained in tap water and higher yet in the nutrient lettuce broth. Copper sulphate N/800 is fatal to all of the spores and only 10 per cent. germination was found in the N/1600. The per cent. of germination increased almost in proportion to the weakening of the solution beyond this point. In the case of the Bordeaux filtrate it is seen that the first filtrate was fatal to all the spores while the second did not prevent germination at all.

To test the longevity of ascospores, collections were made on cover glasses and placed away in sterile petri dishes. These were tested in duplicate or triplicate the first and second day and every seventh day thereafter until no germination was apparent, using either lettuce broth or 4 per cent. sugar solution as the medium. The results of these tests appear below:

TABLE XI.—SHOWING LONGEVITY OF ASCOSPORES.

Age in Days.	1	2	7	14	21	28	35	42	49	56	63	70	77	84	91
Per Cent of Germination.	100	100	25	50	50	65	10	50	50	90	75	95	90	90	50
Medium Used in Cultures.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	4% Sugar.	4% Sugar.	4% Sugar.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	4% Sugar Solution.

TABLE XI—Continued.

Age in Days.	98	105	112	119	126	133	140	147	154	161	168	175	182	189
Per Cent of Germination.	90	75	75	50	75	50	25	10	1	0	0	0	0	0
Medium Used in Cultures.	4% Sugar Solution.	4% Sugar Solution.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.	Lettuce Broth.

While there is considerable fluctuation in the results the gradual falling off in germinations after the 125th day and the total lack of germination after 154 days or about 5 months seems to indicate that the ascospores do not live longer than this time. It is to be noted that the spores in these instances were kept dry. If they were allowed to become moist, as through absorption of water from a humid atmosphere, they immediately germinated. It is thus apparent that their only condition of longevity is in a dry state and that the results reported above therefore, represent their maximum life. Under other, perhaps under all normal conditions, their life is undoubtedly short.

In some cases cultures of ascopores in the sugar solution were examined after 26 hours. It was found that while at first growth had been normal, Fig. 26a, very much distorted hyphæ, Fig. 26b, occurred in abundance and that the distorted cells were vacuolate after the manner of old hyphæ.

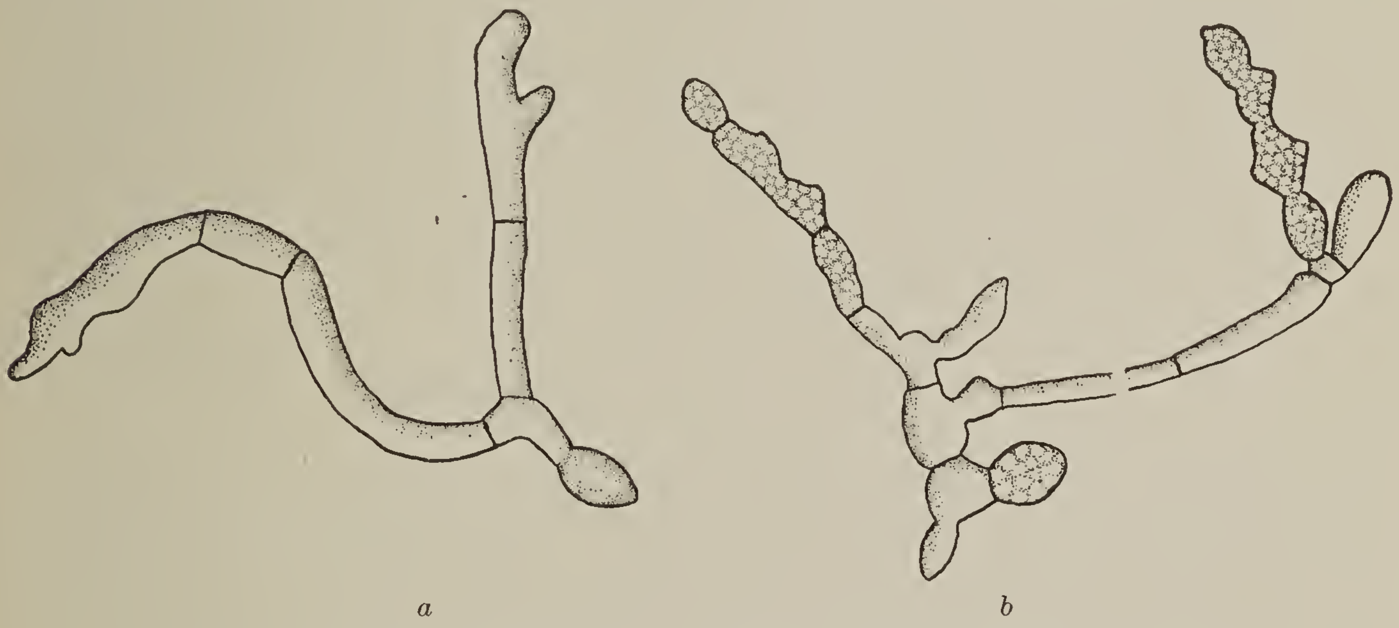

Fig. 26.—Germinating ascospores. *a*, Normal; *b*, abnormal from sugar solution.

Infection by Ascospores.

The question of infection conditions is one of highest importance. Many tests were made to determine under what conditions ascospores could produce infection. The following trials are typical:

A number of fresh, healthy lettuce leaves was placed in culture dishes and inoculated with ascospores in the ways indicated below.

The checks were exact parallels of the inoculations but without spores. The results of these inoculations are shown in the following table:

TABLE XII.—REGARDING INFECTION BY ASCOSPORES.

Number of Leaves Inoculated	Methods of Inoculation	Surface of Leaf Inoculated	Number of Leaves Infected in 7 Days
10	Ascospores in lettuce broth	Upper	6
10	Ascospores in lettuce broth	Lower	0
10	Ascospores in water on bruised spot of leaf	Both	5
10	Check	Upper	0
10	Check	Lower	0
10	Ascospores in water	Upper	0
10	Ascospores in water	Lower	0
5	Ascospores at needle-prick	Upper	0
5	Ascospores at needle-prick	Lower	0

It is noted that the only infections occurred in the presence of the nutrient lettuce broth or at the bruised spots where, virtually, broth existed. This lack of ability of the spores alone, or in water merely, to infect was of such importance that repeated tests of this point were made.

Thus on November 21, 1907, ten lettuce leaves were inoculated upon the upper surface with ascospores in sterile water and on December 3, 1907, there was still no sign of infection.

On November 21, 1907, fifteen lettuce leaves were inoculated upon the lower surface with ascospores in sterile water and on December 3, 1907, there was still no sign of infection.

In both of these cases the leaves, kept in a damp chamber in ordinary room temperature, were fresh and healthy at the end of the experiment, even at the marked spots where the spores were placed. On December 4, 1907, spores were washed from the leaves which had been inoculated but which had shown no infection. Upon microscopic examination in all cases where the spores were found it was seen that they had germinated in a normal way but with no branching of the mycelium or flattening of its end. It was thus made clear that the lack of infection was not due to non-viability of the spores.

On December 4, 1907, sixteen lettuce leaves were inoculated in a damp chamber with spores placed in lettuce broth together with small pieces of lettuce leaf; of these, nine leaves became diseased in seven days while seven showed no infection. At the same time sixteen more leaves were prepared in the same way except that sterile water was used in place of the lettuce broth. In this case none of the leaves showed infection on the seventh day and it was not until the twelfth day that any signs of infection were seen. The leaves had by that time wilted badly and these three cases can not be regarded as cases of parasitism.

To still further study infection by ascospores leaves were inoculated as is indicated in Table XIII. In the case of the inoculations with mycelium the vigorously growing mycelium was placed upon cover glasses in a drop of lettuce broth so that only the tips of the mycelium could touch the leaf by growing over the edge of the cover glass. The leaves were kept in culture dishes so as to preserve a humid atmosphere.

TABLE XIII.—REGARDING INFECTION BY ASCOSPORES.

Number of Leaves	Surface of Leaf	Ascospores + Sterile Water	Ascospores + Lettuce Broth	Mycelium
10	Upper	No leaves infected	No leaves infected	10 leaves infected
10	Lower	2 leaves infected	10 leaves infected	10 leaves infected
10	Bruise	2 leaves infected	10 leaves infected	10 leaves infected
10	Control	No leaves infected	No leaves infected	No leaves infected

Summarizing all of the experiments upon this point, it appears that direct infection by ascospores seldom, if ever, occurs but that infection from the mycelium follows in 100 per cent. of the cases. Spores placed upon a lettuce leaf in lettuce broth with a small bit of torn lettuce leaf also gave a reasonably high per cent. of infection. The use of a drop of lettuce broth upon the leaf in which to place the spores also usually gave infection. In only two cases, however, of all the trials made did any infection result from placing spores upon the leaves in pure water or upon the bare surface of the leaf. In view of this very small percentage of positive results we are not willing to accept this as evidence that the fungus can ever enter upon its parasitic existence without at first having attained vigorous headway saprophytically.

Parasitism and Saprophytism.

The fungus is clearly a saprophyte under many conditions as is attested by its luxuriant growth on various nutrient media and upon dead organic matter. That it may be parasitic as well is obvious from its inroads upon lettuce in our experiment beds and in many commercial beds of this State. The exact degree of its parasiticism and the extent to which it can exist as a saprophyte can, however, only be told by careful experimental work. Since these relations are of great economic significance, with strong bearing upon methods of prophylaxis, close attention was given to ascertain under what conditions and at what stages of its development this fungus is capable of paracitism and how long and upon what nutrients it can exist as a saprophyte, and in particular to what extent it can exist in and migrate through soil.

The following additional test of ascosporic infection was made. Thirty lettuce leaves were placed in culture dishes and upon the first ten was placed sterile soil, upon the second ten sterile soil with ascospores upon the soil. At the edges of ten other leaves small pieces of manure were placed with ascospores on the edges of the manure which were farthest away from the lettuce leaf.

There was no infection in either the first or second case through soil while in the third case the spores germinated, grew over the manure and speedily caused the disease upon each of the ten leaves. It appears from this and other experiments previously quoted that ascospores are not capable of direct infection of the lettuce plant but that the germ tubes formed from the ascospores must acquire a considerable strength and develop a vigorous mycelium by a saprophytic habit before they can bring about infection of healthy tissue. Even the nutriment present in ordinary rich soil will not give the mycelium vigor sufficient to produce infection.

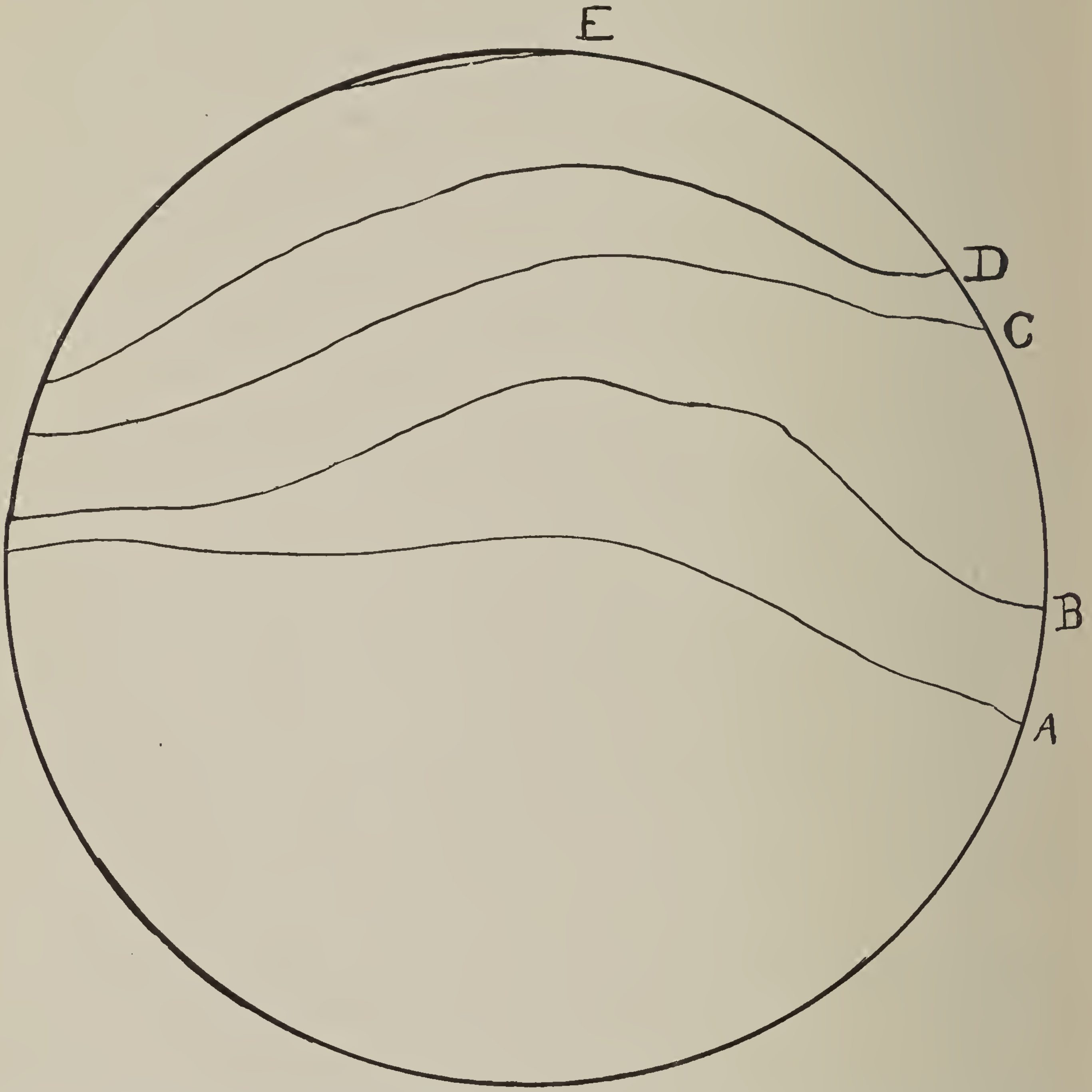

Fig. 27.—Diagram showing rate of invasion of a lettuce leaf by Sclerotinia. Each zone represents one day's growth.

To fully demonstrate the parasitism of the ordinary vigorous mycelium the following test was made: On December 30, 1907, ninety-six plants in outdoor beds were inoculated at various places with masses of vigorously growing mycelium, some placed as near the center of the head as was possible without tearing the plant seriously, others by laying the mycelium upon the lower leaves on the shaded side of the plant. All of these plants showed clear cases of infection at the end of fifteen days or earlier, and all the plants were dead and dried up on the first of April, 1908.

To determine the rapidity of growth of the mycelium of the fungus in a plant and its migration through the tissues of the plant a leaf, after it had become infected on one edge, was placed in a large petri dish and daily record was made of the growth of the mycelium by marking the outside of the plate. The daily growth as is shown by the accompanying diagram, Fig. 27, was on an average, about 11 mm., while the maximum for a single day was 15 mm. and the minimum for the same period 8 mm. The lines of the diagram indicating the growth each day, represent as nearly as possible, the place where the green and uninfected portion of the leaf joined the translucent or infected portion. The average temperature for the five days was 54.5 degrees F. with a maximum of 75 degrees and a minimum of 39 degrees.

After the mycelium exhausts the food supply from the portions of the plant which are attacked, it reaches into the air or over the earth; no aerial mycelium is noted upon newly infected tissue.

The Maximum Infection Distance for Mycelium.

A few lettuce leaves were placed on moist sand in a glass dish, inoculated and kept covered. After a vigorous growth had developed and the originally infected leaves were nearly consumed fresh leaves were placed at various distances from the infected mass. The maximum distance at which leaves were infected in this way, i. e., the maximum distance that the fungus could travel under such conditions, was 2.5 cm. White mycelium might be seen with the naked eye to a distance of about 8 mm. from its source of nourishment, no farther. A very few small sclerotia formed on the naked sand near the lettuce leaf.

In order to determine to how great a distance the mycelium would spread over strictly non-nutritious surfaces small pieces of lettuce leaf were laid in a large sterile petri dish and inoculated with mycelium. The dish was then placed in a moist chamber. The following is the record showing the distance to which the mycelium spread, using various amounts of lettuce leaf for inoculation.

It is evident that with a very small amount of lettuce from which to draw nourishment the mycelium spreads only a short distance. By increasing the amount of nutrient material the distances to which the mycelium can spread is increased up to a maximum of about 22 or 23 mm. It is thus apparent that the spread of this fungus over a soil to any great distance, unless the soil provide nutrient material, is not to be feared. It is noted also in this experiment with the small amount of nutrient material such as 50 sq. mm. of lettuce leaf no sclerotia are formed. With as much as 100 sq. mm., however, a sclerotium, though small, was made.

Mycelium was placed so that its tips only might come in contact with a lettuce leaf. In twenty-four hours it had grown to the leaf, and had developed holdfasts at each point of contact. Each holdfast was surrounded by a translucent spot 1 to 2 mm. in diameter. In twenty-four hours more the tissues were translucent to a distance of about 2 cm. in each direction from the point of original infection, though there was no development of mycelium external to the leaf except near the petiole where the nutriment afforded by the tissues was apparently exhausted.

TABLE XIV.—SHOWING DISTANCE OF MYCELIAL GROWTH, ON GLASS.

Amount of Lettuce Leaf	Distance of Mycelial Growth	Remarks
4 sq. mm	4 mm	About equally in all directions.
50 sq. mm	7 mm	
100 sq. mm	8 mm	Irregularly, one small pin-head-sized sclerotium was formed.
200 sq. mm	18 mm	Irregularly, one small pin-head-sized sclerotium was formed.
400 sq. mm	23 mm	Irregularly, one small pin-head-sized sclerotium was formed.
900 sq. mm	22 mm	Irregularly, one small pin-head-sized sclerotium was formed.

Numerous attempts were made to infect lettuce leaves with soil taken from beneath diseased plants and which was known to contain the mycelium, since it was clearly visible to the naked eye.

Thus, on February 8, 1908, fifty lots of such infected soil were taken was aseptic precautions by a sterilized spatula and placed upon healthy lettuce leaves in sterile culture dishes and dampened with sterile water. No infection resulted. It seems from these tests that the mycelium can not migrate far through soil and retain its infecting efficiency without additional organic food.

Hosts.

While this species of fungus has been reported upon many hosts it is notable that during all of our work of the past four years, involving the inspection of many infected beds in many localities, only two cases of the attack of this fungus in lettuce beds upon any plant other than lettuce have come under our observation. One of these cases was as follows:

A garden pea about 30 cm. high of vigorous though somewhat forced growth, was bent over into contact with the mycelium of the diseased lettuce leaf in the experiment mentioned on page 127. In eight days the distal end of the pea, some 12 cm. long, had been killed. Mycelium was breaking out through it in numerous wooly patches and sclerotia had begun to form. The fungus had also migrated some 9 cm. toward the root and for about 5 cm. the stem was covered with floccose mycelium (Fig 28). The invasion of the pea stem continued until the entire plant was killed.

In the other case B. B. Higgins observed a plant of Lamium which lay amid a mass of sclerotinized lettuce and had become infected. Both of these cases are exceptional. This rarity of infection of plants other than lettuce points somewhat strongly to specialization of the fungus or to very low resistance by the lettuce plant.

Sclerotinia libertiana has been reported on many other hosts and has been found in North Carolina upon a few others besides lettuce. B. B. Higgins brought it into the laboratory on cabbage and a sclerotium disease that appears to be identical with it was sent to the Experiment Station from Mebane by S. K. Scott upon crimson clover and by B. T. Pierce from Charlotte upon alfalfa. According to all appearances of the mycelial growth and formation of sclerotia these are identical but as the sclerotia were not large enough to produce asci and ascospores no comparative data on those structures were obtainable.

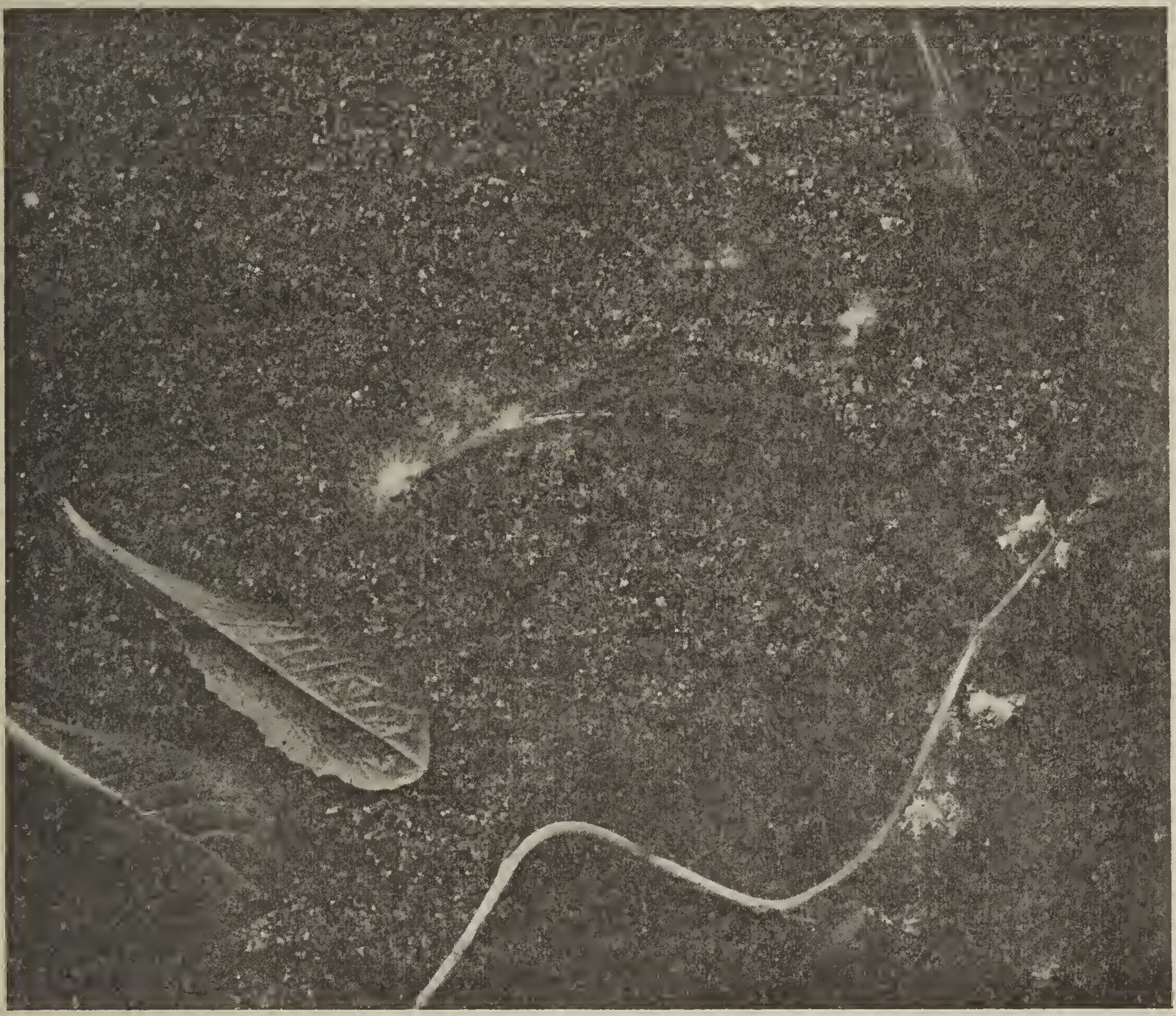

FIG. 28.—Showing healthy leaves and two infected leaves lying upon soil; also an infected pea vine.

Among the hosts upon which the fungus has been reported are the following:

Upon Hemp in Russia, 1868.
" Potato in England, 1883.
" Bean in Germany, 1886, and in Holland.
" Petunia in Germany, 1886.

Upon Zinnia in Germany, 1886.
" Hemp in Alsace, 1891.
" Hollyhock in England, 1891.
" Cucumbers in Massachusetts, 1893.
" Mulberries in France, 1897.
" Sunflower, Dahlia, Eimia, Beets in Holland.
" Artichokes in France, 1899.
" Carrots in France, 1899.
" Chicory in France, 1899.
" Tomatoes in Massachusetts, 1900.
" Cauliflower in Missouri, 1905.
" Cabbage in Missouri, 1905.
" Artichokes in France, 1905.
" Forsythia in Switzerland, 1905.
" Lemon in California, 1907.
" Omphalodes in Switzerland, 1909.

Also upon Ægopodium, Cerefolium, beets, radish, chicory, mustard, rape, caraway, parsley, celery, fennel, vetch, clover.

Field Observations.

Study of diseased plants in New Bern in 1906 showed that the plants were generally attacked on the lower leaves at spots where they touched the soil. The fungus then worked both ways, toward the stem of the plant and toward the tip of the leaf, though it stops its migration in the latter direction very soon owing to the lack of moisture. Growing toward the stem of the plant it soon reaches the leaf axil and there forms masses of white cottony mycelium and eventually sclerotia. The greater number of sclerotia are formed here although some are formed at other points especially among the leaves that lie upon the ground.

Some time was spent sifting the soil, looking for sclerotia formed the previous year. From a bed that was badly infected it was difficult to get an average of more than one sclerotium from each two-quart sifter of soil.

Many germinated, disk-bearing sclerotia were found, nearly always in the front of the beds where the soil was shaded nearly all of the time. When disk-bearing sclerotia occurred in other parts of the beds it was always either in places where they could not be disturbed by cultivation or in beds that had not been recently cultivated. Germinated sclerotia were especially abundant under lettuce plants where they were both shaded and protected from mechanical disturbance. In the case of about half of the affected plants the diseased portion was either directly over a disk-bearing sclerotium or the faces of near by disks were turned toward the infected plant. In the latter case the plants invariably showed more disease upon the side of the plant nearest the disk. It was no uncommon thing to see clouds of spores discharged from disks in the field.

Disks were found upon sclerotia that were located at a depth of 1 1-2 inches in the soil. In no case were sclerotia found upon or among the roots of a plant that had just died. The root was always still perfectly sound, even after the aerial portion of the plant was entirely dead and in no case were sclerotia found in the soil until the root had had sufficient time to rot.

General Relation of the Fungus in Nature.

From the facts above adduced experimentally and from field observation it is seen that *Sclerotinia libertiana,* which is the actual cause of the disease under discussion, propagates and spreads by means of its ascospores produced from the germinated sclerotia and by its mycelium.

The ascospores are comparatively short-lived, even under the conditions most favorable to their longevity. In condition of nature, subject to alternate dryness and atmospheric humidity they would invariably germinate and in the absence of favorable nutrient pabulum, die. Thus the ascospores can not function to any large degree as a means of carrying this fungus over periods of time of any considerable duration.

The mycelium has also been shown to be of comparatively short-life and to retain its infecting power but a short time in the absence of nutriment. This, too, can not be regarded as a means of carrying the fungus over long time intervals. Any possibility that the mycelium may remain alive in soil that has borne sclerotinized plants is very remote, probably non-existent. The sclerotium is long-lived and well adapted to perpetuate the fungus. It alone, of all the structures of the fungus, is able to live for sufficiently long periods to bridge over seasons adverse to the growth of the fungus or long periods of time when no food is available.

The fungus may, therefore, be likened to an annual plant, all parts of which except the seed die at the approach of winter, the sclerotium in this instance acting the rôle of the seed.

The sclerotia rest during the period of inactivity of the disease, that is from the harvest of one lettuce crop until the next crop is present under suitable weather conditions to permit of infection. They then germinate and produce apothecia with a crop of myriads of ascospores.

These ascospores have been shown unable to directly infect healthy lettuce leaves. They may germinate in the film of dew upon the plant but can not force entrance into its tissue and can only perish. Neither are mere wounds ordinarily sufficient to allow infection. The ascospores must at first sustain a period of saprophytic existence until the mycelium developing from it attains a certain degree of vigor. To do this the ascopores must fall upon and germinate upon organic matter, dead moist leaves or other plant parts or particles of manure or some other similar dead organic substance. A dead lettuce leaf or torn fragment of leaf serves its purpose admirably. If the saprophytic existence of the sporeling be upon organic matter which lies very near a lettuce plant the vigorous mycelium may reach over to it and parasitize it.

In cases where the ascospores fall upon dead lettuce leaf fragments still in contact with the live lettuce plant the infection bridge is open. If the ascospores fall upon organic matter separated by some centimeters from the lettuce plant the organic matter there available will be consumed and the mycelium will perish without any infection resulting. In some instances when the food supply is fairly large new sclerotia may be formed. Migration of the mycelium through the soil in efficient infecting condition, for any considerable distance, does not occur, even in soils bearing a large amount of organic matter as reckoned by the horticulturist.

Infection from plant to plant is governed by these same conditions. If the infected plant lie sufficiently near to the uninfected one, the distance can be bridged by the mycelium, but this does not occur at any great distance, usually not over a few centimeters.

That infection from plant to plant does not bridge over any large distance is shown by many observations of healthy plants standing, surrounded on all sides, by dead sclerotinized plants.

Attempts to Control the Disease.

According to Stone[9] the lettuce sclerotiniose became so bad in many green-houses in Massachusetts that many growers lost practically their whole crop from this cause. Disinfection of the soil, however, proved practicable under green-house conditions.

Two principal methods of soil disinfection were early used (1) by means of chemical solutions; (2) by means of heat. The first of these methods has been proved to be unsatisfactory and impractical in most cases. The second has been of a very great benefit.

One of the earlier methods for heating the soil was to sprinkle it with hot water. This was of some value but not entirely effective and moreover it possessed the disadvantage that it left the bed so wet that it had to remain idle for considerable time in order to become dry enough to be worked.

The substitution of steam as a disinfectant followed and it is today used with considerable success under green-house conditions. There are three ways in which steam may be used: (1) by placing 2-inch drain tile permanently under the soil in rows 16 inches apart, more or less as circumstances dictate, and flooding them with steam; (2) by laying perforated steam pipes upon the soil in the middle of the bed and throwing the soil from the sides upon them, then heating by steam, and after steaming pulling out the pipes to use elsewhere. The soil is then covered with canvas for several hours; (3) by a harrow-like arrangement, of pipes. Fig. 29. The teeth of the harrow are perforated on all sides to allow the steam to escape into the soil. The teeth are driven into the soil to a depth of perhaps 10 inches and heated to 208 degrees F., and this temperature maintained as long as is desired.

The disinfection of green-house soil in some of these ways has been used in Rhode Island,[20] Vermont.[21] Ohio,[22] and some other States, nearly always with beneficial results.

In Kentucky,[11] a drop* is reported to have been checked by subirrigating and placing a mulch of excelsior under the plants to prevent their touching the soil.

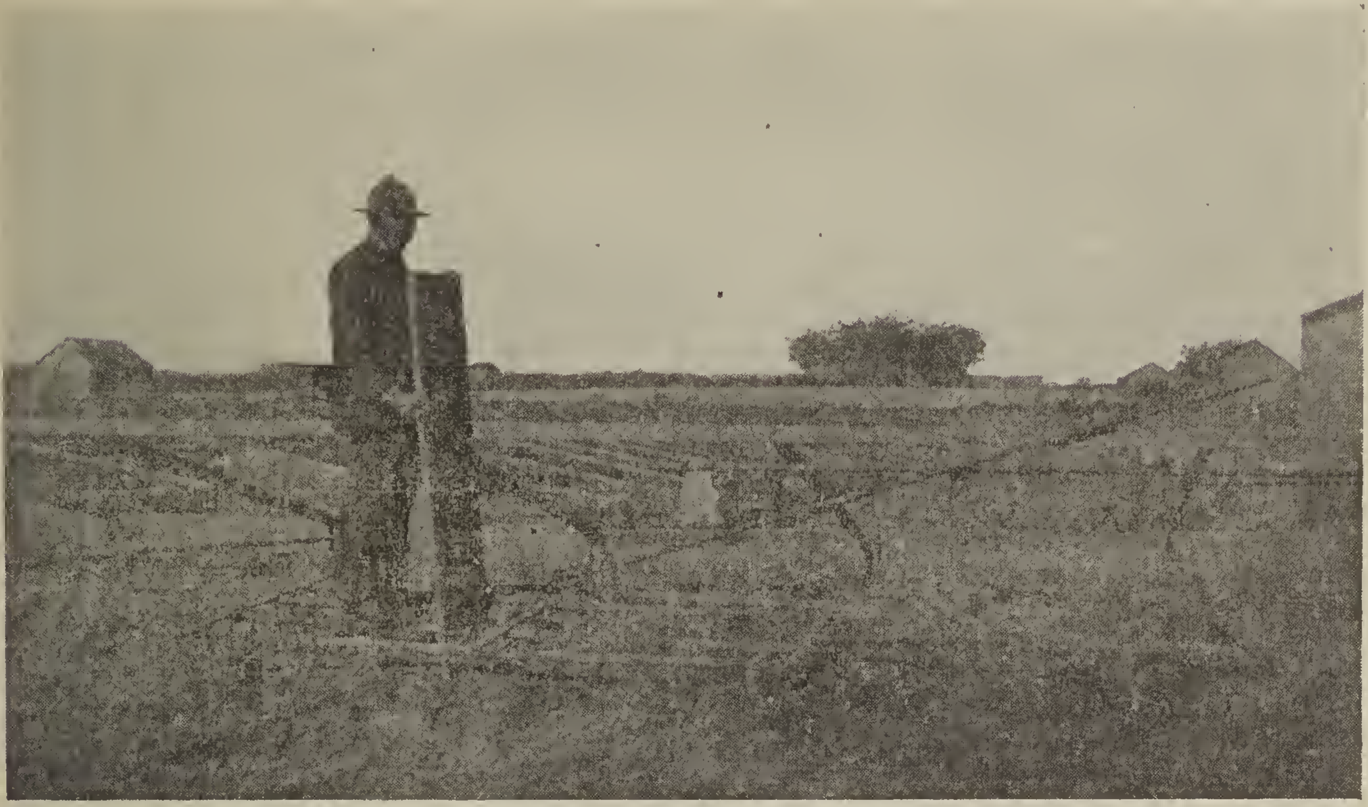

FIG. 29.—Steaming the soil by means of Sargent's sterilizer.

To test the applicability of the above well-known methods to the cold frame and field conditions of the South, numerous experiments were planned and carried out at New Bern and West Raleigh, some of which were as follows:

Experiment 3. To test the efficiency of soil disinfection by heat. One-half of a bed designated as Bed A was prepared by laying 2-inch drain tile 10 inches deep and about 13 inches apart with the ends all running into cross tile as shown in Fig. 30. Thermometers were placed in the soil, care being taken not to place any of them over the rows of tile.

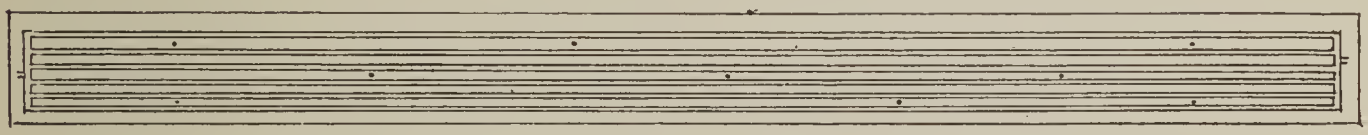

FIG. 30.—Showing the arrangement of tile in box used for steaming the soil for top dressing. Ends of tile, *b*, were closed with cement.

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*It is uncertain whether this was sclerotiniose or some other form of drop.

TABLE XV.—SHOWING TIME AND TEMPERATURE IN SOIL STERILIZATION EXPERIMENTS.

Time	12:30	12:45	1:00	1:15	1:30	1:45	2:00	2:15	2:30	2:45	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15
Therm. a	8	10.5	14	21	25	35	45	46	55	65	74	78	85	90	95	60	70	89	95	95
" b	8	10.5	13	17	21	25	31	38	40	45	50	56	59	63	66	69	72	75	76	80
" c	9	9	10	14	20	30	40	57	70	80	89	94	51	63	85	90	95	95	95	95
" d	7	10.5	22	30	36	46	50	55	60	65	70	74	76	85	50	69	85	90	90	95
" e	8.5	9	9	9	11	11	13	15	15	17	22	28	33	41	57	80	92	95	95	95
" f	10	11	11	11	11	11.5	12	13	14	16	18	19	23	38	67	90	92	95	95	95
" g	7.5	8	8.5	8.5	9	9	9	10	10	10	11	11	12	14	20	28	60	74	80	90
" h	8	8.5	9	9	9	9	9.5	9.5	10	10.5	10.5	11	11.5	12	12.5	20	40	59	72	80
" i	8	8.5	8.5	9	9	10	10	10	10	10	10	10.5	11	12	21	60	95	95	95	95
Steam pressure in lbs.	65	60	60	60	58	45	60	60	60	60	65	60	60	60	65	60	60	60	60	60

Records were taken of the temperature at each thermometer every 15 minutes from the time steam was turned on until the end of the steaming, also of the steam pressure on the boiler (see table).

In this bed were planted 1,260 lettuce plants, care being taken to prevent the carrying of the disease into the bed from other infected beds; of these plants 88 or 6.98 per cent. had the characteristic disease. In the control bed, B, of 1,260 plants there were only 38 that showed the disease. This discrepancy may be accounted for by the fact that infection was worse in Bed A, before it was treated; but it is evident that such steaming did not give promise as a method of control.

Beds G and H were steamed with the Sargent Sterilizer, Fig. 29. The sterilizer was covered with heavy canvas during use. Beds G and H were each 30 feet long, and together they contained 696 plants. The soil was heated to 90 to 95 C., in less than 10 minutes, and that temperature maintained for thirty minutes. Of the 696 plants, 33 or 4.8 per cent. showed the disease, and again considerably more than in the control.

Experiment 4. To test the efficacy of top dressing with disinfected soil. The ends of three separate beds, C, B, and E, were used because these were more convenient to the steam connection with the boiler house.

A box was made 2 x 6 x 4 feet, thus capable of holding 48 cubic feet of soil. Soil was skimmed from the surface of the three beds; to a depth of one inch from E, of two inches from D, and of 3 inches from C, making in all a total of 150 cubic feet or approximately three times the box full. Soil was placed in the box to half fill it, then a system of drain tile was laid upon this soil and enough more soil was placed upon the tile to fill the box. Steam was turned on through the inlet, the ends of the drain tile being stopped with cement. The soil was heated to 90 degrees C. and kept at that temperature for one hour. This soil, after heating, was then scattered over the beds from which it had been taken and the disinfecting box filled again. Care was taken to sterilize the shovels each time after unsterilized soil had been handled with them.

The results of this top dressing of the beds is shown in the following table.

TABLE XVI.—SHOWING EFFECT OF TOP DRESSING WITH STEAMED SOIL

Bed	No. of Plants in Bed.	Healthy Plants	Diseased Plants	Percentage of Disease	Depth of Top Dressing
E	320	399	21	7.02	1 inch
D	320	304	16	5.26	2 inches
C	320	308	12	3.89	3 inches

It is seen that the disease decreased with the increase in depth of the disinfected top dressing.

Experiment 5. To determine the effect of carbon bisulphide, one litre per square metre. One-half of Bed F was treated with carbon bisulphide, and covered with canvas for forty-eight hours, then the canvas was removed and the bed left open. No plants were set until the odor of the carbon bisulphide in the soil had disappeared.

At the time of harvesting the crop there had appeared in the bed 8 diseased plants in a possible 160, which is a slightly smaller per cent. than occurred upon the bed that was top dressed one inch deep. While this treatment seemed to check the disease somewhat it can not be regarded as satisfactory.

Experiment 10. To determine the effect of formalin 1 part to 400 parts of water.

Upon a bed fifteen long formalin of the above strength was sprinkled with a watering pot at the rate of one-half gallon to the square foot. One-half of this solution was applied at one time and the second half two hours later. After sprinkling the bed was left 2 days then stirred with a sterile hoe to aid in drying. Two days later the plants were set out. At harvest time the plants looked better, were more uniform in size, and there were no diseased plants among 160 that the bed contained. The treatment looked promising and the experiment was repeated at West Raleigh in 1908-09, with the result, however, that 62.5 per cent. of the plants were affected.

TABLE XVII.—SHOWING EFFECTS OF SOIL DISINFECTION.

Method	Number of Plants Treated	Diseased Plants in Treated Area	Healthy Plants in Treated Area.	Per Cent of Diseased Plants
Steamed with Drain Tile	1,260	88	1,172	6.98
Steamed with Sargent Sterilizer	696	33	663	4.80
Top Dressed with 1 in. Disinfected Soil	320	21	299	7.02
Top Dressed with 2 ins. Disinfected Soil	320	16	304	5.26
Top Dressed with 3 ins. Disinfected Soil	320	12	308	3.89
Sprinkled with Carbon Bisulphide	160	8	152	5.00
Sprinkled with Formalin at New Bern	160	----------	160	----------
Sprinkled with Formalin at West Raleigh	144	90	54	62.50
Control	1,260	38	1,222	3.02

From the above experiments in attempts at soil disinfection little hope is to be had. Though these means of disinfection may apply well in green-house conditions, it is obvious that they are not satisfactory in extensive cold frames. Whether some other method of soil treatment may not be devised, we can not, of course, say. Theoretically, it seems possible, but that these means mentioned above are of practical service, seems very doubtful.

PRACTICAL CONSIDERATIONS.

The rational method of eradication of this pest based upon the facts here adduced would seem to be the same as that practiced against an annual plant, which if not allowed to produce new seeds will eventually, upon the growth of all old seeds, be brought to the end of its existence.

Sclerotia are not formed in diseased plants until the nutriment in the part affected is consumed, that is not until the plant has given clear easily discerned evidence of the presence of the parasite. If all such plants be pulled and burned no sclerotia will be made. The few small roots remaining in the ground will not usually be affected at this stage and even if they are, the formation of sclerotia in the roots under the ground is not common. This practice of constant removal of the sclerotinized plants will prevent the formation of new sclerotia and in course of time the sclerotia already present in the soil will have either decayed or germinated and thus become harmless. As an additional precaution it is well to kill all mycelium which may be left in the locus of the removed plant by a liberal application of some disinfectant such as copper sulphate. It appears that this line of treatment is the most promising in cases where the destruction of the sclerotia by steam is not practicable.

Since the ascospores are harmless except through the threshold of dead organic matter upon which to begin growth as saprophytes the careful removal from the bed of all torn, injured, sick or dead lettuce leaves should be practiced and manure and organic matter of other kinds had best be removed from the surface of the beds in the neighborhood of plants or covered so as to remove them from ascosporic infection. Similarly any injury to the plants as tearing the leaves, etc., which would result in dead bits of leaf, should be scrupulously guarded against.

Since frequent stirring of the soil inhibits production of ascospores it will be well to rake over the top soil to a depth of a half-inch once each week.

The above methods are of general application either in field or greenhouse. In addition to this soil disinfection, though it has not proved practicable in field or under canvas, is of great value under glass.

BOTRYTIS AND SCLEROTINIA.

Some species of Sclerotinia are genetically connected with Botrytis as a conidial form, notably:

Sclerotinia fuckeliana has as conidial form *Botrytis cinerea* Pers.
Sclerotinia vaccinii has as conidial form a Monilia.
Sclerotinia cinerea Sch. has as conidial form *Monilia cinerea Bon.*

These facts together with the sometime association or botryose and sclerotiniose upon the same plant very naturally led to the assumption that the Botrytis of the lettuce sustained genetic connection with Sclerotinia libertiana upon the lettuce.

Conflicting views have been held upon this point. Thus DeBary[23] as early as 1886 held that *Sclerotinia limertiana* had no true conidial form while some other species of the genus did produce Botrytis conidia. Humphrey[5] of the Massachusetts Agricultural Experiment Station says that the rotting of lettuce is due to *Botrytis vulgaris* Fr. which "is with little doubt the conidial stage of some sclerotium producing Peziza (Sclerotinia)." Stone and Smith[8] of the same station accepted this conclusion, but in 1898 and 1899 an extended study of *Sclerotinia libertiana* led them to believe that the Botrytis upon lettuce was not the conidial form of this Sclerotinia. Ramsey[13] of Wisconsin in 1904 considered the "drop" (Sclerotinia) as distinct from Botrytis. Hume[12] of Florida in 1901 believed this Sclerotinia to be entirely distinct from Botrytis.

Finally, Wulff,[24] also Westerdijk,[25] in recent papers upon these fungi, accept the conclusion that *Sclerotinio libertiana* has no Botrytis conidial stage.

Our experiments and observations bring out clearly the following facts:

1. That sclerotiniose may prevail in beds for months with its characteristic white mycelium with no accompaniment of botryose.
2. That botryose may similarly prevail in other beds with no accompaniments of sclerotiniose.
3. That in all of our cultures of these two fungi extending over an aggregate of some seven years, involving thousands of tube and plant inoculations, there has never occurred an instance of apparent change, in any way, from one of these forms to the other.
4. That the sclerotia of Sclerotinia differ in size and general appearance from those of Botrytis, and that in cases of botryose the sclerotia of Sclerotinia are not produced.
5. That the sclerotia of Botrytis invariably produce hyphæ and conidia upon germination, and that the sclerotia of Sclerotinia never do so.
6. That the sclerotia of Sclerotinia invariably produce ascospores, or at least abortive attempts to do so, while the sclerotia of Botrytis never do so.

We believe therefore that the evidence is sufficient to warrant the conclusion that these two fungi and the diseases caused by them are distinct and that one bears no present relation to the other, whatever their phylogenetic relation may be.

PART II.*

A Practical Test of a Curative Treatment.

The conclusions as recorded above, deduced from several years of laboratory and field study of this disease, especially those conclusions which point to the sclerotia as the only means of hibernation, began to force themselves upon the mind of the senior author some years ago.

Those conclusions seemed to be so unavoidable and their logical effect upon horticultural practice so fundamental and so significant that it was deemed imperative to put the question to a crucial test. If the theory as enunciated be true, all that is necessary in order to rid a Sclerotinia-infected lettuce bed of its pest is to prevent the formation of new sclerotia in it for a period of two or perhaps three years.

To make such a test the first essential was a bed thoroughly and unquestionably infected and so located and managed that it would not be subject to aerial or other extraneous infection.

The experimental lettuce beds of the Experiment Station located on the farm at West Raleigh are reasonably well isolated from any other infected beds which might furnish air-borne ascospores to bring about reinfection. Precaution could easily be taken to prevent access of sclerotia through manure or other sources. The beds are two in number, each 208 feet by 9 1-2 feet in size, 30 inches high on the north side, 8 inches on the south side, and are covered in the usual way by canvas supplemented when need be by burlap mats. They accommodate eight rows of plants, 77 plants to the row, with a total capacity, therefore, of 1,232 plants. The beds were to some extent infected owing to the nature of the experimental work that had been conducted in them. This infection was not, however, considered sufficient to make the test crucial.

The first step, therefore, was to thoroughly infect the beds and to demonstrate that they were so infected and to secure a record of the degree of infection. This was accomplished in the spring of 1908 by inoculating several rows or about 67 plants of the then large nearly mature marketable lettuce with Sclerotinia mycelium. Within a few days, April 18, the plants so inoculated all collapsed and followed the usual course of the disease. These plants and considerable other lettuce refuse as well were allowed to remain on the ground and since the plants were large the number of sclerotia that remained on the soil was very great. Thorough infection seemed sure. The lettuce was followed by cucumbers and in the autumn of 1908, October, the crop was put in in the usual commercial way and the record of disease for that year presented in Table XVIII and in Diagram I (Fig. 31), shows clearly that a full and thorough infection had been produced.

The plants, it will be seen, began to die of sclerotiniose in December and in January they were dying rapidly. The last record of disease was on March 16, 1909. A total of 545 plants had died of sclerotiniose or over 45 per cent. of those in the beds.

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*Printed in part in an earlier Bulletin. (26.)

To make records of disease the beds were inspected carefully each day and the cause of disease was determined by culture or microscopic examination or both, so that no doubt could exist on this point.

The work so far demonstrates thorough infection of the beds.

The second step of the test consisted in removing the plants before new sclerotia could form in order to determine whether by so doing the bed could in the course of a few years be freed from infection.

TABLE XVIII.—DAILY RECORDS OF DEATHS FROM SCLEROTINIOSE, 1908-1909.

Date	Number of Plants Diseased	Date	Number of Plants Diesased
Dec. 3	1	Jan. 2	3
5	2	4	9
14	1	8	10
20	2	11	41
24	2	13	29
11	21	15	12
18	2	17	10
20	11	20	24
21	2	24	73
22	8	26	94
23	2	Feb. 1	10
25	5	5	33
26	8	8	6
2	4	10	57
28	3	12	41
29	4	16	25
		Total	555

The daily inspection was most rigid. All suspected case of sclerotiniose were closely watched and as soon as the symptoms became reasonably indicative of this disease the plants, entire, were removed to the laboratory. *Thus no sclerotia were allowed to mature in the beds.* As an additional precaution the locus of the diseased plants were sprayed with a strong Bordeaux mixture.

The lettuce was followed by cucumbers and in the autumn, October 15, 1909, the next crop of lettuce was set.

It now remained to see whether the disease had increased, as it would have done under the usual modes of handling, or whether a decrease had been brought about by the hygienic treatment that had been followed.

The record of disease was kept precisely as in the preceding year and the same methods were taken to prevent maturity of sclerotia.

The record is presented in Table XIX and in Diagram II (Fig. 31).

TABLE XIX.—DAILY RECORDS OF DEATHS FROM SCLEROTINIOSE, 1909-1910.

Date	Number of Plants Diseased
Feb. 18	1
March 4	1
22	1
28	1
31	2
Total	7

It will be noted that no plants died of sclerotiniose prior to February 18, 1910, and none after March 31, and *that in all only seven plants or one-half of one per cent. of the crop died.*

This very large decrease in disease under one year of hygienic treatment—about 99 per cent. of the disease had been removed—was more than was anticipated and indicates even shorter life of the Sclerotia and greater loss of sclerotia from rotting than was predicated for them.

The beds were again set with lettuce in December, 1910.

This year approximately the usual number of plants, or to be exact, 1,113 in all, were set. The crop was raised to maturity, cut and sold. The record of disease is shown in Table XXI and in Diagram III (Fig. 31).

TABLE XX.—DAILY RECORDS OF DEATHS FROM SCLEROTINIOSE, 1910-1911.

Date	Number of Plants Diseased
April 18	1
19	1
20	3
29	1
May 1	1
15	1

Whatever may be thought of the theoretical questions involved, certain practical conclusions stand forth clearly and unmistakably.

1. The lettuce beds were very thoroughly infected. See record of 1908-09, Table XVIII and Diagram I.

2. Under usual conditions and usual mode of handling this disease would not have decreased but would have increased or at least remained destructive during following years.

3. Under the treatment that was followed, which had been indicated as the proper one by our laboratory and field studies, the disease decreased very markedly after one year and remained unimportant during the second year.

Whether the treatment employed here can be expected always to give such satisfactory results under all conditions of soil and climate can not of course be stated.

DIAGRAM I.

WINTER, 1908-1909.

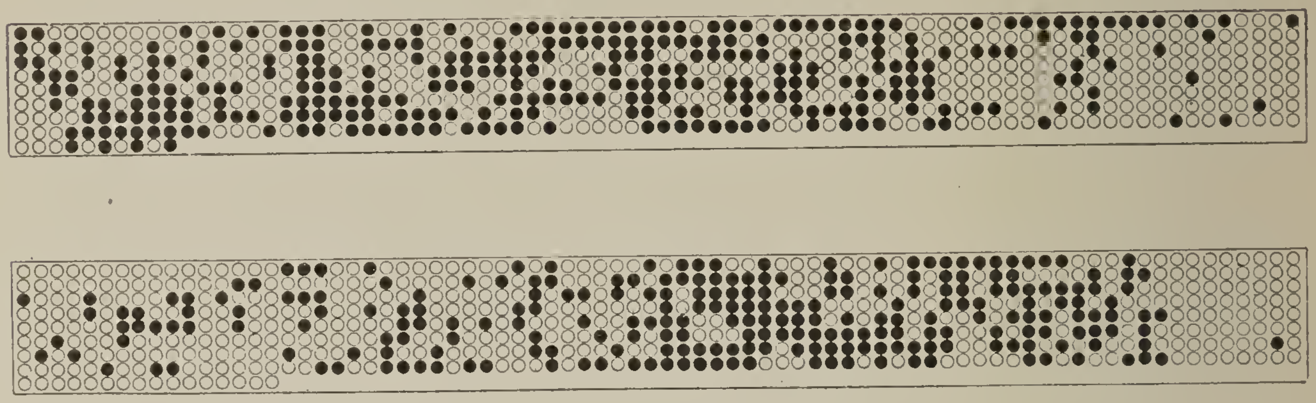

DIAGRAM II.

WINTER, 1909-1910.

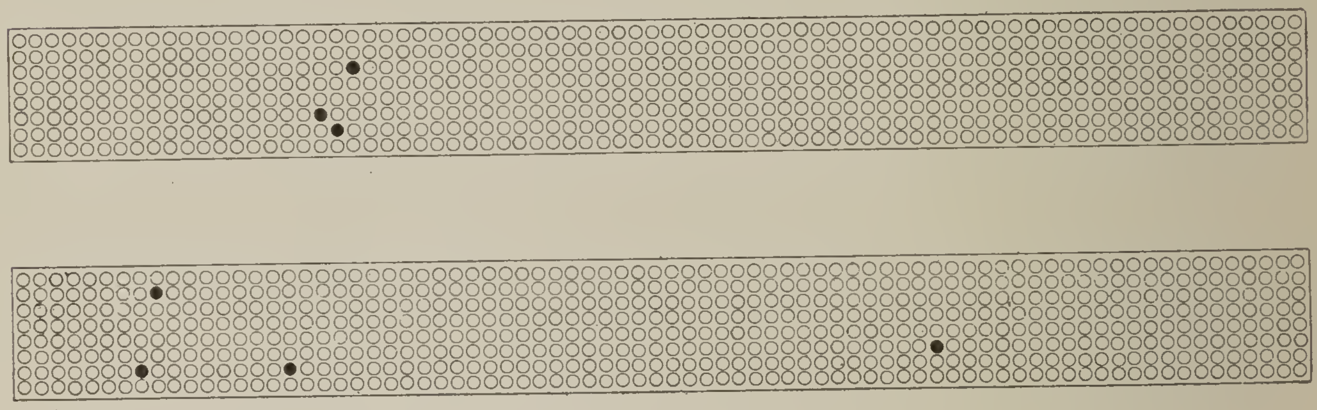

DIAGRAM III.

WINTER, 1910-1911.

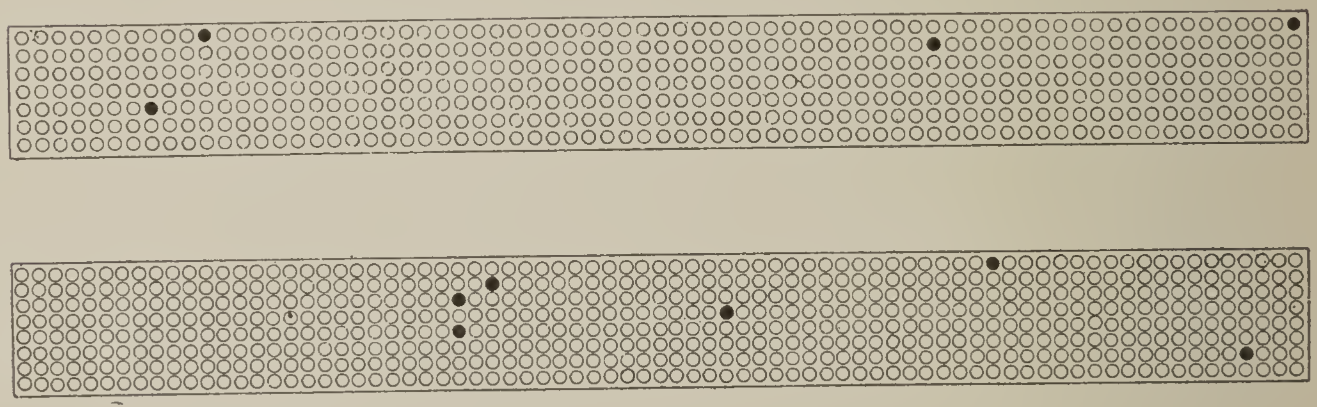

FIGURE 31.—Showing plan of Station beds and the exact location of affected plants in the bed during three seasons. • Diseased plant. o Healthy plant.

The writers feel justified, however, in stating that theoretically this treatment should prove effective and that in the one extremely crucial test to which it has been submitted it has proved thoroughly effective. They feel justified, therefore, in recommending it to lettuce growers who are troubled by this serious disease.

RECOMMENDATIONS.

The following recommendations for the treatment of beds infected with sclerotiniose are made.

1. The bed should be very carefully inspected every day and every plant that shows indications of this disease should be pulled up and burned.

2. The place in the bed from which sick plants are removed should be drenched with Bordeaux mixture or bluestone and water.

If these directions are followed no sclerotia will mature. The number of live sclerotia which will be present in the beds the following year will be very small and the amount of disease will be correspondingly reduced though it is not to be expected that the disease will be entirely eliminated. The next year the same treatment should be followed with just as much care as was given during the first year. Failure to be careful the second year will be fatal to success. It is probable that two years of this treatment will almost, if not quite, eradicate the disease. During later years, however, the beds should be watched closely and the same procedure followed. Beds which have been restored to a state of health and beds from which the disease has been partially eradicated should be protected from all possible sources of extraneous infection. It should be recognized that all refuse that comes from places where this disease exists is liable to bear the sclerotia and convey the disease. Therefore, all refuse from diseased lettuce beds, manure or fertilizer which may contain diseased refuse must be scrupulously avoided. There is also possibility of aerial infection. If infected beds exist nearby there appears to be no possibility of guarding against such infection and the method of treatment here advocated can not be expected to give its maximum of results if infected lettuce beds exist near the beds which are under treatment, since in such cases the danger of reinfection through the air will always be present.

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RELATION OF THE MINERALOGICAL AND CHEMICAL COMPOSITION TO THE FERTILIZER REQUIREMENTS OF NORTH CAROLINA SOILS

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RELATION OF THE MINERALOGICAL AND CHEMICAL COMPOSITION TO THE FERTILIZER REQUIREMENTS OF NORTH CAROLINA SOILS

By J. K. Plummer, Soil Chemist

In the systematic study of soils little attention has been given in the past to the minerals which comprise the greater part of most soils. Since the time of Liebig, investigators have devoted their attention toward determining the amounts of the various elements of plant food, giving little thought to the way these elements were held in the soil.

Much time has been spent in field experimentation and in a study of the physical properties of soils; and more recently the biological side has occupied the attention of many investigators. The results of these different methods of attack have thrown much light on the important problem of producing maximum crops at the minimum cost.

It would appear that a knowledge of the amounts of the various plant food constituents of the soil, from which the plant must draw its nourishment, and the form in which these elements are held would be of the highest importance to the intelligent cultivator of the soil. Taking this information with that afforded by carefully conducted field tests, much light will be thrown on the problem of soil fertility.

This bulletin has been prepared with the end in view of supplying additional information to that which has already been secured as to the nature of the soils of North Carolina. These facts will be helpful in forming a more correct judgment with reference to the future management and treatment in building up a rational system of agriculture in the State.

In the laboratory determinations of the more important elements of plant food have been made on over 1,600 samples of soil in connection with the soil survey of the State. Field experiments of the Division have been running twelve years on soils representing the important types of the three large provinces into which the State has been divided, namely, Mountain, Piedmont, and Coastal Plain. Mineralogical analyses have been made on the sand and silt separates on some three hundred soils by use of the methods described by McCaughey and Fry.[1]

The value of the mineralogical analyses cannot be overestimated, as they reveal the elements as they are found in the soil. These analyses supplement the total determinations by chemical methods. By the chemical analyses the total amounts of the different plant food constituents are obtained, but little information is gained as to the form in which this reserve is stored in the soil, whereas, the mineralogical analyses is mainly concerned in showing the chief forms of combinations in which the potential plant food occurs. With the mineralogical analyses an approximation as to the amount of each plant food constituent may be obtained. Their value lies in showing the form in which the plant food constituents are held. Experience has taught that the arbitrarily chosen solvents for measuring the more available portion of the stored plant food have given conflicting results as to the actual fertilizer deficiencies of soils. By knowing the minerals that carry this stored plant food and the reaction of these minerals toward solution, certainly a more intelligent opinion may be rendered as to the possible requirements of soils for the various fertilizing materials.

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[1] Bulletin No. 91, Bureau of Soils, U. S. Department of Agriculture.

DESCRIPTION OF MINERALS CARRYING PLANT FOOD IN NORTH CAROLINA SOILS.

Potash, the felspars, orthoclase and microcline, and the micas (muscovite and biotite) are the minerals which supply the soils of this State with potash. These minerals are widely distributed and occur in nearly all the soils examined to a greater or less extent. However, there is wide variation in the amounts of these minerals found in the different provinces of the State. In many of the Mountain soils potash is derived principally from the micas, muscovite and biotite furnishing by far the greater part of the potash found in soils of this section of the State. In the Piedmont section, the micas have been replaced to some extent by the felspars, but in many of the soils of this region, the former minerals furnish much of their potash supply. Orthoclase and microcline are the predominant potash-bearing minerals of the Coastal Plain, the micas occurring only as traces in many of these soils.

Often orthoclase fragments assume a fibrous appearance and are rounded in contour, as though they had been weathered to some extent. Microcline always shows well preserved faces and sharp edges, apparently having been very little affected by natural agencies, which are constantly operating in the soil. Biotite or black mica readily forms alteration products, passing over into chlorite and epidote. In this mineral the potash is held in the more available form than in any other mineral found in our soils. It contains considerable oxide of iron, which is very likely responsible for the readiness with which this mineral is decomposed. Muscovite, from its optical properties, appears to weather little or none, but there is evidence that this mineral does give up its potash with greater readiness than do the felspars.

RESULTS BY OTHER INVESTIGATORS WITH POTASH MINERALS.

E. Blanck[2] gives results of comparative tests in pot experiments with various silicates as the source of potash. He finds that the micas furnish a more available supply of this constituent than do the felspars.

D. N. Praenishnikov[3] found that in comparing the potash silicates as the source of potash for plants, biotite and muscovite were superior to the felspars as carriers of potash.

Fraps[4] reports that all the potash is extracted from biotic with strong HCL, about one-third from muscovite, and only a small percentage from orthoclase and microcline. He states that practically no potash is removed from orthoclase and microcline by one-fifth normal nitric acid, less than 10 per cent. from biotite, and 15 per cent. from muscovite.

These conclusions are borne out in our field experiments, which will be discussed more in detail in the following pages.

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[2] Jour. Landw. 61, 1913, No. 1, pp 1-10.

[3] Landw. Ves. Stat. 77, 1912, pp 399-411.

[4] Tex. Station Bulletin 145.

LIME.

The lime bearing minerals are epidote, hornblende, garnet, and the plagioclase or lime-soda felspars. Calcite so valuable for its content of calcium carbonate, has been found in but one instance. This was in a soil which had a marl bed three feet beneath the surface. Epidote has been found present in all the soils examined. This is a metamorphic mineral, and its wide distribution can be accounted for by its mode of formation, being one of the final products from the alteration of the more easily decomposable minerals augite, hornblende, and micas. It occurs as thick fragments, showing little signs of having undergone chemical decomposition.

It is epidote that furnishes the greater part of lime for many of the soils examined. Hornblende alters to chlorite and epidote, giving up some of its lime in the process of alteration. This mineral furnishes lime in a more easily accessible state for use by the plant than any except the felspars. It often occurs in fragments in which one end of the crystal shows alteration to epidote and the other part remains as hornblende. Garnet has not been found as commonly as has epidote and hornblende. It occurs in thick grains, often rounded in contour. The plagioclase felspars have been found in many of the soils of all three provinces of the State, however, they are most abundantly encountered in the Mountain and Piedmont Sections. In none of the soils do these minerals exist to a great extent, probably due to the ease with which they are decomposed; supposedly giving up their lime in the form of carbonate. It is in the form of the felspars that lime under natural conditions is most available to plants in North Carolina soils. Also these minerals furnish much of the soda which may replace or drive out potash from its state of combination in the finer particles of soils. Augite has been found in some of the soils and is quite common in those of the Iredell series.

Another alteration product of hornblende, the principal decomposition product of biotite, is chlorite, an aluminum, magnesium silicate. It is in chlorite that much of the magnesium is held in North Carolina soils, especially those of the Coastal Plain section.

PHOSPHORIC ACID.

Apatite is the only mineral found in North Carolina soils which carries phosphoric acid to any extent. In very few instances has this mineral been found in the soils of the Coastal Plain. This is in accord with the total chemical analyses. The soils of the Piedmont and Mountain sections contain apatite to a much larger extent, but here the amount is only a trace. More often than otherwise, this mineral is found included in quartz and other minerals; in this form it is doubtful if the plant can draw much of its phosphoric acid from this source. Compared to potash, lime, and magnesia bearing minerals, apatite occurs as mere traces in our soils.

Rutile, zircon, toumaline, sillimanite are common minerals of these soils, but as these have little or no plant food value, a description of them will not be given here.

Magnetite, an oxide of iron, is a common mineral of our soils, and is of value in furnishing iron to plants.

Quartz is by far the most predominant mineral existing in most of the soils of North Carolina, the only exception being those of the Iredell Series. In this series quartz is subordinate to epidote and hornblende. Much information can be obtained by a close observation of the quartz fragments as to the conditions through which a soil has passed. These fragments are often rounded, showing that erosion has taken place and that they have been subjected to great leaching. Especially is this true of the soils of the Coastal Plain.

In many of the Coastal Plain soils, especially those of the Portsmouth series, an abundance of animal remains, phytolitharien, sponge spicules, or rhizopoda casts are found. The presence of these animal remains indicate that at some previous time these soils were covered with water. This may be responsible for the low state of productivity of these soils.

Invariably the silt separates contain a larger amount of plant food bearing minerals than do the sands, and in the Piedmont and Mountain sections these minerals have suffered greater decomposition than those in the sands. Often the silt separates from the Coastal Plain soils present pure clean faces, as though little alteration had taken place.

As quartz is the most abundant mineral found in these soils, and as it has no plant food value so far as is known, in the mineralogical examinations, the author has done as McCaughey and Fry did; compared the other minerals to quartz, and knowing no better way to show the mineralogical composition, have tabulated these analyses after their fashion.

Mountain Soils.

Classification.—The soils of the Mountain section are somewhat analagous to those of the Piedmont Plateau, but in all cases they have been considered as belonging to separate series. All the upland soils encountered so far in the detail soil survey have been considered as belonging to the one broad series known as Porter's. The various types of this series have been formed from schists, gniesses, and granites. The individual types are more dissimilar, perhaps, than is commonly the case, but it has not seemed possible to form a new series in any of the areas so far surveyed. With the extension of the survey to other counties, it is possible that representative types of other soil series will be formed. There is little doubt, however, that the great bulk of the upland falls within the present limits of the Porter's series. The two extensive upland soils are loam and sandy loam, while three other types are represented by smaller areas. These are the clay, sand, and black loam.

The valley and bottom land soils are included in the Toxaway series. These are of alluvial origin, modified by colluvial wash, and have been formed from washing of the Porter's series, and deposited by streams. The surface of these soils is flat, or level, with a gradual slope toward the streams. They lie at sufficient elevations above the normal water level of the streams so as to be fairly easily drained. However, most of these soils are subject to frequent overflow. The two types thus far found are the Toxaway loam and Toxaway fine sandy loam.

LOCATION OF EXPERIMENTAL FIELDS.

Field experiments are being conducted on four of the more important of these mountain soils. The data therefore secured and published can be applied to practically all of this section.

The mountain work is located at the following places:

1. The Buncombe Test Farm, about midway between Black Mountain and Swannanoa in Buncombe County. This is one of six test fields owned and operated by the State Department of Agriculture.
2. The Hendersonville field, one mile northeast of the railroad station at Hendersonville, Henderson County, on the farm of B. W. Marshall.
3. The Blantyre field, one mile northeast of Blantyre, on the farm of Charles Baldwin. These last two fields are in easy walking distance from stations of Hendersonville and Black Mountain or Swannanoa.

RESULTS ON THE BLANTYRE FIELD.[5]

The Blantyre Field is typical Porter's clay, and is representative of much of the heavy upland soils of the mountains. It consists of twelve one-twentieth acre plats. This field was established in the spring of 1910. Corn was grown on all the plats, it being the first crop of the following three-year rotation.

First Year.—Corn.
Second Year.—Wheat.
Third Year.—Red clover.

The following materials were used as carriers of the different elements of plant food:

Dried blood for nitrogen.
Acid phosphate for phosphoric acid.
Potassium sulphate for potash.
Rock lime for lime.

The rate of application is based on the amount of the various plant foods known to be removed by maximum crops. In the case of corn 100 bushels was taken as a maximum yield. This may seem high to some, but many such yields are yearly obtained in the State and over twice this amount has been produced on a measured acre. Even on this very much depleted field, we obtained a yield of nearly sixty bushels by the use of commercial fertilizers alone. In order to secure the required amount of plant food it was necessary to apply the following amounts of materials:

Dried Blood.—1,062 lbs.

Acid Phosphate.—350 lbs.

Sulphate of Potash.—170 lbs.

Lime was applied at the rate of 1,000 pounds of rock lime per acre.

The following table gives the treatment and the yield of each of the plats:

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[5] See N. C. Dept. Agr. Bul., Vol. 32, No. 5, for details of field results for Mountain Section used his Bulletin.

TABLE 1. RESULTS ON PORTER'S CLAY. CHAS. BALDWIN'S FARM, BLANTYRE, TRANSYLVANIA CO., N. C.

Plat No.	TREATMENT	Yield per Acre		Increase	
		Grain, Bushels	Stover, Pounds	Grain, Bushels	Stover, Pounds
1	None	23.1	1590	----------	----------
2	Lime (CaO)	28.4	2030	5.3	440
3	Nitrogen	26.7	2020	3.6	430
4	Phosphoric Acid	39.0	2200	15.1	860
5	Potash	19.7	1180	—4.2	—160
6	None	23.9	1340	----------	----------
7	Nitrogen, Phosphoric Acid	55.0	3360	31.1	2020
8	Nitrogen, Potash	28.7	2810	4.9	1470
9	Phosphoric Acid, Potash	40.1	2130	15.7	780
10	Nitrogen, Phosphoric Acid, Potash	52.7	3240	28.3	1870
11	None	24.4	1370	----------	----------
12	Lime, Nitrogen, Phosphoric Acid, Potash	59.8	3850	35.4	2480

Average gain for Nitrogen	10.3	1128
Average gain for Phosphoric Acid	22.0	895
Average gain for Potash	—.85	110
Average gain for Lime (CaO)	6.2	525

These results certainly indicate that phosphoric acid is needed first on this soil. Acid phosphate alone gave an increase of over fifteen bushels per acre. Nitrogen alone gave an increase of only 3.57 bushels, but when applied in addition to phosphoric acid it gave an increase of sixteen bushels, nearly one bushel more than did phosphoric acid over no fertilizer. Potash alone gave a smaller yield than no fertilizer, very little increase when applied in addition to nitrogen or phosphoric acid separately, and a decrease in the addition of these together.

TABLE 2.—CHEMICAL AND MINERALOGICAL COMPOSITION OF

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2-3 inches----2,000,000 lbs Subsoil, 28 inches-------8,000,000 lbs				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil 1187	*Inches* 0-8	1,055	618	12,312	1,419	*Percent.* 29	*Percent.* 33	Biotite, muscovite, orthoclase.
Subsoil 1188	10-36	2,012	8,742	102,182	7,562	27	36	Biotite, orthoclase, muscovite, epidote.

Lime gives fair increase, either alone or in addition to a complete fertilizer, the gain over no fertilizer being at the rate of 5.3 bushels, and in addition to all these elements at the rate of 7.1 bushels, making an average of 6.2 bushels per acre. This would indicate that lime could be used at a profit on this soil.

While it is not safe to draw definite conclusions from one season's work, the marked benefit of phosphoric acid and nitrogen certainly justifies the assumption that the phosphoric acid and nitrogen supply must be increased in order to produce large crops permanently.

A study of Table No. 2 will certainly aid in the interpretations of the results obtained from this field.

The surface 6⅔ inches of this soil contains enough potash for nearly 375 one-hundred bushel corn crops. This potash is principally in the form of biotite and muscovite, there is some orthoclase in the sand particles, but the silt is mainly micas. Twenty-five such crops would, if all the phosphoric acid was available, require an amount of phosphoric acid equal to the total amount existing in the surface 6⅔ inches. The mineralogical analysis shows that much of this phosphoric acid is in the form of inclusions in quartz, and that it is exceedingly doubtful if the plant can obtain this phosphoric acid at all. The nitrogen supply for one-hundred bushel crops is limited to about twelve years. Lime in this soil is principally in the form epidote, there is, however, some hornblende present.

RESULTS ON THE HENDERSONVILLE FIELD.

The Hendersonville Field is located on typical Porter's sandy loam and is exceptionally uniform throughout. There are eleven plats in this field, the nine fertilized ones receiving the same treatment as the corresponding ones on the Blantyre Field. This field, too, was established in the spring of 1910, and corn was grown the first year.

PORTER'S CLAY, BLANTYRE, HENDERSON COUNTY.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite,	Epidote, hornblende, zircon, rutile, microcline, apatite, as inclusions in quartz	Epidote, chlorite hornblende, rutile, zircon, magnetite, microcline	Biotite is altered and fresh. Orthoclase is fresh. Some secondary quartz.
Biotite, muscovite, orthoclase	Chlorite, hornblende, rutile, zircon	Chlorite, hornblende, rutile, zircon, microcline, magnetite	Biotite badly altered. Orthoclase shows signs of weathering.

The following table gives the treatment and yields of corn in 1910:

TABLE 3. RESULTS ON PORTER'S SANDY LOAM. B. W. MARSHALL'S FARM, HENDERSONVILLE, HENDERSON CO., N. C.

Plat No.	TREATMENT	Yield per Acre		Increase	
		Grain, Bushels	Stover, Pounds	Grain, Bushels	Stover, Pounds
1	None	22.6	1680		
2	Lime (CaO)	35.7	2400	13.1	720
3	Nitrogen	39.1	3160	16.5	1480
4	Phosphoric Acid	20.6	1680	—2.0	0
5	Potash	20.6	1760	—2.3	240
6	Nitrogen, Phosphoric Acid	53.7	2840	30.8	1320
7	Nitrogen, Potash	37.1	2400	14.2	880
8	None	22.9	1520		
9	Phosphoric Acid, Potash	27.3	2280	4.4	760
10	Nitrogen, Phosphoric Acid, Potash	64.3	3840	41.4	2320
11	Lime, Nitrogen, Phosphoric Acid, Potash	70.3	3920	47.4	2400
	Average gain for Nitrogen			25.8	1210
	Average gain for Phosphoric Acid			11.6	410
	Average gain for Potash			3.3	270
	Average gain for Lime (CaO)			9.6	400

There is a striking difference in the results on this field compared to those on the Blantyre field. Here we find no apparent gain from phosphoric acid alone, but nitrogen alone gave an increase of 16.5 bushels. When phosphoric acid was applied in addition to nitrogen we find it gave a large increase. Here, as at the Blantyre field, we find phosphoric acid and nitrogen gave the largest increase, but their relative importance is reversed. Potash alone or in combina-

TABLE 4.—CHEMICAL AND MINERALOGICAL COMPOSITION OF

Laboratory Number	Depth to Which Sample Was Taken	POUNDS OF TOTAL PLANT FOOD CONSTITUENTS PER ACRE Surface, 6 2-3 inches....2,000,000 lbs. Subsoil, 28 inches.......8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil 1189	*Inches* 0-7	418	605	34,375	16,750	*Percent.* 36	*Percent.* 43	Muscovite, biotite, orthoclase, epidote
Subsoil 1190	9-36	1,524	2,494	75,280	54,034	44	46	Muscovite, biotite, epidote, orthoclase

tion with nitrogen gave slight decreases in yield, but in the case of plats 9 and 10 where applied with phosphoric acid, and with nitrogen and phosphoric acid, the yields were larger than on plats 4 and 5. The increase of number 10 over number 6 is very marked, so much so that it brings up the average gain for potash to 3.3 bushels per acre as compared to a loss of .85 bushel on the Porter's clay.

Lime alone gave an increase of 13.14 bushels and in combination with nitrogen, phosphoric acid and potash, 6 bushels. This large increase in lime is probably due to the liberation of the plant food supply in the soil, especially nitrogen.

Table 4 gives the chemical and mineralogical composition of this field.

The chemical analysis of this soil shows that there is enough potash in the surface 6⅔ inches to furnish a supply for maximum crops for nearly 1,000 years. While the greater part of this potash is in the form of the micas much of it is in the form of the felspars, especially orthococlase. The biotite content here is comparatively fresh in the topsoil, little of it showing alteration to chlorite. This mineral, however, does show alteration in the subsoil. The phosphoric acid content is about the same as in Porter's clay in the Blantyre field, all apatite encountered is the form of inclusions in quartz. The nitrogen supply in this soil will not furnish a one hundred bushel corn crop for over 5 years.

Results on the Buncombe Test Farm.

This farm which contains some 300 acres, is owned and operated by the State Department of Agriculture. It includes a large section of Swannanoa valley land, which is representative Toxaway loam, and considerable tillable upland which is typical Porter's loam. Fertilizer results on this farm should be applicable to extensive areas in practically all the mountain counties of the State.

PORTER'S SANDY LOAM, HENDERSONVILLE TEST FIELD.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Muscovite, biotite, orthoclase	Microcline, zircon, plagioclase, hornblende, magnetite, rutile, chlorite, apatite as inclusions	Zircon, hornblende, plagioclase, magnetite, rutile	Potash bearing minerals are well preserved. Quartz grains are angular to subangular.
Muscovite, biotite orthoclase	Microcline, rutile, zircon, plagioclase, hornblende, pyroxene, chlorite, magnetite	Hornblende, rutile, zircon, chlorite, microcline, plagioclase	Some of the minerals show deep seated chemical alteration. Orthoclase is quite fresh. Quartz subangular, and some secondary.

TOXAWAY LOAM.

Field "A" was established in 1908, but excessive floods destroyed the 1909 crop, so only two years are given. This soil is typical Toxaway loam, and was in corn for each of the three years.

The results are given in table 5.

TABLE 5. RESULTS ON FIELD A, BUNCOMBE FARM, 1908 AND 1910.

No.	TREATMENT	Yield per Acre						Average Increase		Value of Increase	Cost of Fertilizer	Profit
		Grain, Bushels			Stover, Pounds							
		1908	1910	Avr.	1908	1910	Avr.	Grain	Stover			
1	NP	22.7	18.7	20.7	1395	1100	1248	14.2	398	$11.53	$3.66	$7.87
2	NK	5.2	.0	2.6	533	0	267	—3.9	—584	—5.07	2.70	—7.77
3	PK	33.0	21.1	27.1	2565	1360	1963	20.6	1113	18.87	1.50	17.37
4	None	11.0	2.0	6.5	1170	530	850	--------	--------	------	------	------
5	NPK	37.2	28.5	32.9	2700	1580	2140	26.4	1290	23.64	3.93	19.71
13	None	14.5	3.7	9.1	1710	410	1060	--------	--------	------	------	------
18	Lime	33.1	13.7	23.4	1725	800	1263	14.3	203	10.82	2.50	8.32
19	Lime, NPK	41.0	36.8	38.9	3289	1780	2535	29.8	1475	26.76	6.43	20.33
17	Manure, P	39.3	28.7	34.0	3000	1460	2230	24.9	1170	22.11	2.79	19.32
Gain for N		4.2	7.4	5.8	135	220	177	--------	--------	4.77	2.43	2.34
Gain for P		32.0	28.5	30.3	2160	1580	1870	--------	--------	28.69	1.23	27.46
Gain for K		14.5	9.8	12.2	1305	480	893	--------	--------	11.97	.27	11.70
Average gain for Lime		11.2	9.5	10.4	302	295	299	--------	--------	8.48	2.50	5.98

TABLE 6—MINERALOGICAL AND CHEMICAL COMPOSI

Laboratory Number	Depth to Which Sample Was Taken	POUNDS OF TOTAL PLANT FOOD CONSTITUENTS PER ACRE Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches-------8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil 1203	*Inches* 0-10	3,160	3,320	33,800	20,560	*Percent.* 46	*Percent.* 54	Biotite, muscovite, epidote
Soil 1204	*Inches* 12-36	2,579	438	135,763	64,873	55	63	Biotite, muscovite, epidote

The same carriers of plant food were used as sources of nitrogen, phosphoric acid and lime as previously stated, but the potash was obtained from manure salt instead of sulphate of potash. The rate of application was on the arbitrary basis of a 7-2½-1½ mixture. Three hundred pounds of this was the amount applied to the normal plat in 1908 and 400 pounds in 1910. This would give 21 pounds of phosphoric acid, 7½ pounds of nitrogen and 4½ pounds of potash per acre in 1908, and 28, 10 and 6 pounds, respectively, in 1910.

It is evident that there were larger increases wherever phosphoric acid was used. In the lower part of the table the amount of increase was obtained by deducting the yield on plat, which received nitrogen and potash, from that on plat 5 which received a complete fertilizer. Thus, on account of the soil of plat 2 being of different character the application of phosphoric acid alone would very probably not have shown so great an increase as this table indicates. Likewise the yield for potash, 12.2 bushels per acre, is too great since it represents the difference between the yield on plat 1 and on plat 5. The same discrepancy arises in the increase of 5.8 bushels due to nitrogen. However, these figures represent the relative importance of the three elements when applied to this dark phase, Toxaway loam.

Lime was applied alone and in combination with nitrogen, phosphoric acid and potash. In both cases it gave material increases in yields as shown by the results on plats 18 and 19. It is of interest to note in this connection that the yield on plat 18 which received lime alone dropped from 33.1 bushels in 1908 to 13.7 bushels in 1910. It is very probable that this temporary beneficial effect of lime alone in 1908 was due to liberation of the plant food of the soil.

In table 6 is found the mineralogical and chemical composition of this soil.

This soil shows an abnormally high potash content and the micas supply practically all this potash in the sand particles. Biotite in

TION OF TOXAWAY LOAM, BUNCOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite	Hornblende, orthoclase, microcline, rutile, zircon, plagioclase, magnetite, apatite as inclusions in quartz	Hornblende, chlorite orthoclase, microcline, plagioclase	Biotite is for the most part fresh. Biotite, epidote and muscovite comprise most of the minerals other than quartz.
Biotite, muscovite	Hornblende, orthoclase, microcline, rutile, zircon, plagioclase	Hornblende, chlorite, orthoclase, microcline, plagioclase, rutile	High percentage of potash bearing minerals. Micas compose principal part. Some biotite altered.

the surface soil is for the most part in a fresh condition, as is usually the case more alteration has taken place in this mineral in the subsoil. In the surface soil there is considerably more phosphoric acid than is usually found in our soils, the principal portion of this element of plant food is in organic form or as inclusions in quartz fragments. It is quite possible that the marked increase in yield on plat 18 where lime was used alone was due to the liberation of phosphoric acid from the organic matter. In the subsoil of this field there is only 438 pounds

TABLE 7. RESULTS ON FIELD B, BUNCOMBE FARM, 1908 AND 1909.

Plat No.	TREATMENT	Yield per Acre						Average Increase		Value of Increase	Cost of Fertilizer	Profit
		Grain, Bushels			Stover, Pounds							
		1908	1909	Avr.	1908	1909	Avr.	Grain	Stover			
1	NP	30.3	20.0	25.2	4470	1335	2903	.2	911	$ 3.78	$ 3.13	$ .65
2	NK	18.6	13.9	16.3	3390	1058	2224	—8.7	232	—5.16	2.31	—7.47
3	PK	34.8	16.7	25.8	2903	930	1917	.8	—75	.26	1.28	—1.02
4	None	33.2	16.8	25.0	2850	1133	1992	--------	--------	------	------	------
5	NPK	41.2	17.6	29.4	3608	1110	2359	4.4	367	4.55	3.36	1.19
13	None	30.1	18.0	24.1	2685	1140	1913	--------	--------	------	------	------
18	Lime	35.6	16.2	25.9	2993	983	1988	1.8	75	1.56	.63	.93
19	Lime, NPK	46.0	21.0	33.5	3315	1230	2273	9.4	360	8.02	4.62	3.40
17	Manure, P	47.4	23.7	35.6	3420	1073	2247	11.5	334	9.39	2.59	6.80
Gain for N		6.4	.9	3.7	705	180	442	--------	--------	4.36	2.08	2.28
Gain for P		22.6	3.7	13.1	218	52	135	--------	--------	9.71	1.05	8.66
Gain for K		10.9	—2.4	4.2	—862	—225	—544	--------	--------	.76	.23	.53
Average gain for Lime		5.2	.8	3.0	8	—19	—6	--------	--------	2.08	1.26	.82

TABLE 8.—MINERALOGICAL AND CHEMICAL CO

Laboratory Number	Depth to Which Sample Was Taken	Pounds of Total Plant Food Constituents per Acre Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches--------8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil 1201	*Inches* 0- 8	1,458	1,726	14,385	2,513	*Percent.* 25	*Percent.* 27	Muscovite, biotite,
Soil 1202	*Inches* 10-36	1,420	776	64,000	11,360	28	33	Biotite, muscovite

of phosphoric acid to a depth of 28 inches which bears out the assumption that most of this material is in the organic form. Nitrogen in this field is also higher than is commonly found in these soils. The lime content here is principally in the form of epidote, with hornblende next, and the plagioclase felspars occurring in small amounts.

Porter's Loam.

Field "B" is located on representative Porter's loam. It consists of 19 plats, with the same plan of treatment as field "A" on the Toxaway loam. The same materials were used and the relative applications for the plats have been the same. However, the normal application was at the rate of 300 pounds per acre for both years.

The plats included in table 5 correspond to those of field "A" in table 3.

We find that phosphoric acid again gives us the largest increase in grain, but the average gain is greater for nitrogen. There is little difference in the average gain in grain for nitrogen, potash or lime. However, though the nitrogen is credited with a gain of 442 pounds of stover per acre, both potash and lime failed to increase the stover over no fertilizer.

Here, as in all the soils examined from this section of the State, there is enough potash to supply the need of crops for many hundred years to come. As in most of these Mountain soils, this potash is held in the form of micas. The biotite content of this field is quite fresh showing little alteration to chlorite or epidote. The potash felspars occur here in limited amounts. In the sand separates there is not over 5 per cent of the minerals other than quartz potash felspars. The amount of phosphoric acid in this field is exceedingly small; that which is found in the mineral form is chiefly as apatite occurring as tiny needles inclosed in quartz grains. This field is fairly well supplied with nitrogen, but for maintaining its fertility, this supply will have

MPOSITION OF PORTER'S LOAM, BUNCOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Biotite, muscovite	Epidote, chlorite, hornblende, rutile, zircon, apatite as inclusions, plagioclase	Hornblende, chlorite, orthoclase, microcline, plagioclase, magnetite, zircon	Minerals are comparatively fresh. Micas carry by far the greater portion of potash. Apatite is as tiny needles enclosed in quartz.
Biotite	Epidote, hornblende, rutile, zircon, included apatite, magnetite, orthoclase	Hornblende, chlorite, orthoclose, rutile, zircon, plagioclase	More secondary quartz. Otherwise the subsoil is about the same as soil.

to be replenished considerably. The lime content of this soil is held principally as epidote and hornblende. Only a small amount of the lime-soda felspars are here.

PIEDMONT SOILS.

Results at Iredell Test Farm.[6]

This farm is located near Statesville, well up in the Piedmont (foothill) section of the State. The main type of soil on the farm is Cecil clay loam. The important types in this section are Cecil sandy loam, Cecil clay loam, and Cecil clay, the latter two predominating.

THE TEST PLATS.

The plats on which these experiments were conducted are embraced in Fields A, B, and C. Fields A and B had been long in cultivation and were badly run down when work was commenced. The plats in Field C were part of an old field, covered with broom sedge, small briars, and small pines in 1903 when the State took hold of the property. These plats are one-twentieth acre in size, with space between plats sufficient for two rows of corn or other crops, the rows on either side of each plat being fertilized like the plat which they adjoin.

Field A.—These plats were used for fertilizer experiments with cotton in 1903-4-6-9; for fertilizer experiments with corn in 1905-7; for general crop of oats without fertilizer in the fall and spring of 1908; and for fertilizer experiments with peas in the summer of 1908. In case of each of the three crops, the same plan or system of fertilization was followed. By this is meant that plat 1 in all cases received only nitrogen; plat 2, phosphoric acid; plat 3, potash, and so on, though the quantities actually applied varied with the three crops. The fertilization of cotton plats was based on a normal application of 400 pounds per acre of a mixture containing 7 per cent available phosphoric acid and 2 per cent each of nitrogen and potash. The fertilization for corn was on a basis of 300 pounds per acre of a mixture containing 7 per cent available phosphoric acid, 3 per cent nitrogen, and 1½ per cent potash. For peas, the fertilization was based on a normal application of 300 pounds per acre of a mixture containing 8 per cent available prosphoric acid, 1 per cent nitrogen and 4 per cent potash.

Field B.—These plats were used for fertilizer experiments with corn in 1903-4-6-8; for fertilizer experiments with cotton in 1905 and 1907; for a general crop of oats without fertilizer in the fall and spring of 1909, and for fertilizer experiments with peas in the summer of 1909.

Field C.—These plats were used for fertilizer experiments with peas in 1904-5-6-7; a grain crop without fertilizer preceding the pea crop in each year except 1904; for fertilizer experiments with cotton in 1908; and for fertilizer experiments with corn in 1909.

Table 9 gives the average results for seven years fertilization for corn on these fields, A, B, and C.

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[6] See N. C. Dept. of Agr. Buls. Vol. 31, Nos. 6 and 8, for details of field results for Iredell farm used in this Bulletin.

EFFECT OF NITROGEN, PHOSPHORIC ACID, POTASH, AND LIME ALONE AND IN COMBINATION WITH EACH OTHER ON CORN YIELDS.

The experiments, the results of which are presented in Table 9, were planned to show the effect on the yield of corn of nitrogen (N), phosphoric acid (P), and potash (K) when applied singly, when two of the constituents were applied together, as nitrogen and phosphoric acid (N P), nitrogen and potash (N K), and phosphoric acid and potash (P K), and when all three of these fertilizer constituents were applied to make a complete fertilizer (N P K); also to test the effect of lime (L) when used alone and when used in connection with a complete fertilizer (N P K L).

The results are shown in yields of bushels of shelled corn and pounds of stover per acre for the several years, average yields average increases over the unfertilized (O) plats, which represent the effect of the fertilizer applications, the value of the increase, the cost of the fertilizer, and the value of the increased yield of corn and stover and of corn alone over cost of fertilizer. The value of the increased yield of corn and stover and of corn alone represent the profit from the several fertilizer applications after paying for the fertilizer itself.

In these experiments the corn was cut, shocked and shredded, the stover being all of the plant except the corn on the cob.

Nitrogen, N (Plats 3^2, 1 and 1). During six years the average results on the plats in Fields A and B show decreased yields and in the value of product, while for one year in Field C there was a gain from the use of nitrogen, the average results for the plats in the three fields being an actual loss in both yield and value of product from the application of nitrogen alone. The average annual loss was $1.95 per acre on basis of corn and stover and $1.66 per acre on basis of corn alone.

Phosphoric Acid, P (Plats 4^2, 2 and 2). Phosphoric acid alone produced increased yields in all of the seven years on the plats in the three fields, the average increase for four years in Field B being 6.5 bushels of corn per acre, for two years in Field A 5 bushels, and for one year in Field C 7.4 bushels, or an average for seven years in all three fields of 6.2 bushels, worth at 70 cents per bushel $3.29 per acre for corn alone, or $4.05 for increased yield of corn and stover over cost of fertilizer.

Potash, K (Plats 6^2, 3 and 3). Except the first year in Field B, there was less corn produced on the plats receiving potash alone than on the unfertilized plats, the average for the seven years being slightly less where potash was used than where no fertilizer was applied, and the potash was used at a loss.

Nitrogen and Phosphoric Acid N P (Plats 7^2, 5 and 4). From nitrogen and phosphoric acid increased yields over the unfertilized plats were obtained in all seven years in the three fields, the average annual increase for the four years in Field B being 17.5 bushels of corn per acre; for two years in Field A 22.4 bushels of corn per acre, and for one year in Field C 16.3 bushels, or an average annual

TABLE 9. AVERAGE RESULTS FOR

Number of Plat	FERTILIZER APPLICATION PER ACRE	Pounds of Nitrogen (N) per Acre	Pounds of Phosphoric Acid (P_2O_5) per Acre	Pounds of Potash (K_2O) per Acre	Yield in Bushels of Shelled Corn per Acre		
					1903	1904	1906
5^2–4–8	Unfertilized= O=						
3^2–1–1	69.2 pounds 13% blood= N=	9					
4^2–2–2	150 pounds 14% acid phosphate= P=		21				
(5^2+14^2)-4–8	Unfertilized= O=						
6^2–3–3	22.5 pounds 20% manure salt= K=			4.5			
(5^2+14^2)-(4+11)–8	Unfertilized= O=						
7^2–5–4	69.2 pounds 13% blood= N= 150 pounds 14% acid phosphate= P=	9 	 21				
(5^2+14^2)-(4+11)–8	Unfertilized= O=						
8^2–6–5	69.2 pounds 13% blood= N= 22.5 pounds 20% manure salt= K=	9 		 4.5			
(5^2+14^2)-(4+11)–8	Unfertilized O=						
10^2–8–6	69.2 pounds 13% blood= N= 150 pounds 14% acid phosphate= P= 22.5 pounds 20% manure salt= K=	9 	 21 	 4.5			
(5^2+14^2)-(4+11)–8	Unfertilized= O=						
9^2–7–12^2	150 pounds 14% acid phosphate= P= 22.5 pounds 20% manure salt= K=		21 	 4.5			
5^4–18^2–8^2	Unfertilized= O=						
4^4–14^2–7^2	500 pounds unslaked lime every fourth year L=						
6^4–15^2–9^2	69.2 pounds 13% blood= N= 150 pounds 14% acid phosphate= P= 22.5 pounds 20% manure salt= K= 500 pounds unslaked lime every fourth year= L=	9 	 21 	 4.5 			

—Loss. *By mistake this plat had normal application of potash in 1906. The indications are that this
Checks for plats 5, 6, 7 and 8, Field A, and plats 6^2, 7^2, 8^2, 9^2 and 10^2, Field B, have been obtained from plats
natural fertility between check plats and a corrected check was figured on this basis for each treated plat

increase for seven years in the three fields of 18.8 bushels of corn, worth $10.03 over cost of fertilizer for corn alone, or $13.76 for the increased yield of corn and stover. This was 12.62 bushels more corn, worth $6.74, than phosphoric acid alone produced, showing that nitrogen has added decidedly to the yield and profit when combined with phosphoric acid, though alone it was used at a loss.

Nitrogen and Potash, N K (Plats 8^2, 6 and 5). There were small average increased yields of corn in the three fields from applications of nitrogen and potash combined, the average for the seven years in the three fields being 1.5 bushels per acre, which was not sufficient to pay for the fertilizer This fertilization was therefore at a loss, having cost $1.26 per acre more annually than the value of the increased yield of corn.

SEVEN YEARS IN FIELDS A, B, AND C.

Number of Plat	Yield in Bushels of Shelled Corn per Acre		Yield of Stover in Pounds per Acre					Average Increase in Bushels of Shelled Corn per Acre Due to Fertilizer	Average Increase in Lbs. of Stover per Acre Due to Fertilizer	Value of Increase with Corn at $0.70 per Bushel and Stover at $8.00 per Ton	Cost of Fertilizer per Acre	Value of Average Annual Increase of Corn and Stover Over Cost of Fertilizer	Value of Average Annual Increase of Corn Alone (Not Valuing Stover) Over Cost of Fertilizer
	1908	Ave.	1903	1904	1906	1908	Ave.						
5^2–4–8	------	19.5	------	------	------	------	1785	--------	--------	$------	$------	$--------	$--------
3^2–1–1	------	20.1	------	------	------	------	1712	.6	—73	.13	2.08	—1.95	—1.66
4^2–2–2	------	25.7	------	------	------	------	2003	6.2	291	5.50	1.05	4.05	3.29
(5^2+14^2)-4–8	------	19.1	------	------	------	------	1751	--------	--------	--------	--------	--------	--------
6^2–3–3	------	19.2	------	------	------	------	1781	.1	—113	—.38	.23	—.61	—.16
(5^2+14^2)-(4+11)–8	------	18.5	------	------	------	------	1700	--------	--------	--------	--------	--------	--------
7^2–5–4	------	37.3	------	------	------	------	2633	18.8	901	16.89	3.13	13.76	10.03
(5^2+14^2)-(4+11)-8	------	17.9	------	------	------	------	1650	--------	--------	--------	--------	--------	--------
8^2–6–5	------	19.5	------	------	------	------	1801	1.5	151	1.65	2.31	—.66	—1.26
(5^2+14^2)-(4+11)–8	------	16.8	------	------	------	------	1549	--------	--------	--------	--------	--------	--------
10^2–8–6	------	35.9	------	------	------	------	2308	19.1	1069	17.65	3.36	14.29	10.01
(5^2+14^2)-(4+11)–8	------	16.1	------	------	------	------	1523	--------	--------	--------	--------	--------	--------
9^2–7–12^2	------	3.26	------	------	------	------	2538	16.5	1015	15.61	1.28	14.25	10.27
5^4–18^2–8^2	------	17.6	------	------	------	------	1485	--------	--------	--------	--------	--------	--------
4^4–14^2–7^2	------	16.1	------	------	------	------	1443	—1.47	—42	—1.19	.63	—1.82	—1.66
6^4–15^2–9^2	------	31.8	------	------	------	------	2211	14.2	726	12.84	3.99	8.85	5.95

did not affect the yield, as the average yields for the unfertilized potash plats are near the same.
4 and 11, and 5^2 and 14^2 respectively. It has been assumed that there is a uniform increase or decrease in the between checks.

Phosphoric Acid and Potash, P K (Plats 9^2, 7 and 12^2). Phosphoric acid and potash combined gave increased yields on all the plats in the three fields, the average annual increase for four years in Field B being 15.2 bushels of corn per acre, for two years in A 21 bushels, and for one year in Field C 12.5 bushels, or an average for the seven years in the two fields of 16.5 bushels, worth $10.27 over cost of fertilizer on basis of corn alone, or $14.25 on basis of corn and stover. From this it is seen that potash added to phosphoric acid has increased the yield of corn 10.3 bushels more than phosphoric acid alone, at a profit of $6.98 over cost of fertilizer, showing that potash was effective in corn production on this soil when used in connection with phosphoric acid, but valueless when used alone.

Phosphoric Acid, Potash and Nitrogen, N P K (Plats 10^2, 3 and 6). When all three of the fertilizer materials were used together to make a complete fertilizer, increased yields were obtained on all three plats in the three fields, the average annual increase for four years in Field B being 17.8 bushels of corn per acre, for two years in Field A 21.9 bushels and for one year in Field C 18.7 bushels, or an annual average increase for the seven years in the three fields of 19.1 bushels worth $10.01 over cost of fertilizer on basis of corn alone, or $14.29 on basis of corn and stover.

When compared with each other these results show that nitrogen added to phosphoric acid, potash added to phosphoric acid, and nitrogen and potash added to phosphoric acid have yielded practically the same profits, though nitrogen and phosphoric acid have produced largest average increased yields over unfertilized plats (18.8 bushels per acre), than phosphoric acid and potash (16.5 bushels per acre), and nitrogen, phosphoric acid and potash were larger than either of the other two (19.1 bushels per acre). This indicates that nitrogen is more important on this soil than potash for corn production.

Lime, L (Plats 4^4, 14^2, and 7^2). Lime was applied at the rate of 500 pounds rock or 1,000 pounds slaked lime per acre every fourth year. On the plats in Field B during four years there was a profit of 14 cents per acre from the use of lime On the plats in Field A there was a loss of $9.10 annually per acre, and on the plat in Field C in one year's test a profit of $6.23, the average for the seven years being a loss of $1.66 per acre. The plat in Field C, where there was a profit from the use of lime, had been in peas after grain during four previous years.

Lime with Complete Fertilizer N P K L (Plats 6^4, 15^2 and 9^2). When lime was used in combination with the three fertilizer constituents there was less corn produced on all the plats in Fields B and A than where the three fertilizer constituents were used without lime, but on the plat in Field C, which had previously been in peas and grain for four years, there was a decided gain from the use of lime. As an average of all the tests there was smaller increased yield of corn and profit where lime was used than where it was not.

As an average of all the results, the experiments show—

(1) That nitrogen alone on this soil for the production of corn was used at a loss;

(2) That potash alone had practically no effect on the yield and was used at a loss;

(3) That nitrogen and potash combined increased the yield very slightly but at a loss;

(4) That lime alone, except where peas had been previously grown, was used at a loss;

(5) That phosphoric acid alone gave increased yields and profits in all cases, showing that it is the most important constituent for corn production on this soil;

(6) That nitrogen combined with phosphoric acid added decidedly to the increased yields and profits, the average annual increase for phosphoric acid alone being 6.2 bushels and for nitrogen and phosphoric acid 18.8 bushels per acre;

(7) That potash added to phosphoric acid increased the yields decidedly over phosphoric acid alone, the average annual increase for phosphoric acid alone being 6.2 bushels per acre, and for phosphoric acid and potash 16.5 bushels;

(8) That potash added to nitrogen and phosphoric acid was at a small increase in yield and without profit; and

(9) That the yields from the addition of lime to nitrogen, phosphoric acid and potash were smaller than from the three fertilizer constituents combined.

The most important constituent in producing increased yields and profits on this soil was phosphoric acid. Nitrogen and potash singly or combined, gave good returns when used with phosphoric acid, but were of little or no value when used alone or with each other. Nitrogen added more largely to the yields than did potash.

In table 10 will be found the average mineralogical and chemical composition of plats on Fields A, B, and C.

Though the potash content in this field is much lower than those of the mountain section, we find enough of this element to produce large crops for many years. Here the micas, also furnish much of the potash supply especially in the finer particles of this soil. Orthoclase is very abundant in the sand separates of soils of these plats and it is in a bad state of preservation. The faces present a fibrous looking appearance, resembling an ice crystal as it melts. This soil is supplied with an abundance of lime bearing minerals as epidote, hornblende and the plagioclase felspars. The latter minerals are more abundant than in those fields of the Mountain section examined. The nitrogen supply here is higher than is commonly found in this type of soil, due to the turning under of the pea crop grown on the plats. Phosphoric acid is principally in the organic state, as the amount of apatite found was very small, not enough to anything like furnish the supply shown by the chemical analysis. The apatite found was included in quartz and microcline fragments; in this form it is of very little value for plant use.

COASTAL PLAIN SOILS.

Location of Farm and Character of Soil.[7]

The Edgecombe Test Farm is located near the center of Edgecombe County, on the main road between Tarboro and Rocky Mount, approximately eight miles from either place. It is two miles south of Kingsboro Station.

The main upland soil of this farm is representative of much of the Coastal Plain section of the State. It consists of dark gray sandy to fine sandy loam, eight to twelve inches deep, underlain by yellow sandy clay subsoil. The surface soil is light in texture, and is commonly very deficient in organic matter. It classifies as Norfolk sandy to fine sandy loam. Like most of the sandy soils of the Coastal Plain, the sand content is mostly silica which contains no important plant food. The chemical analyses of the soils of this type show them to be

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[7] See N. C. Dept. of Agr. Bul., Vol. 35, No. 195 for details of field results of Coastal section.

TABLE 10—MINERALOGICAL AND CHEMICAL ANALYS

Laboratory Number	Depth to Which Sample Was Taken	POUNDS OF TOTAL PLANT FOOD CONSTITUENTS PER ACRE Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches=-----8,000,000 lbs ..				Minerals Other than Quartz in		Abundant Mine
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
	Average of 3 samples.							
Soil	*Inches*					*Percent.*	*Percent.*	
1193	0-8	1,174	1,111	8,237	9,126	33	36	Altered biotite, muscovite, weathered orthoclase
1207	0-8							
1209	0-8							
	Average of 3 samples.							
Subsoil	*Inches*							
1194	18-36	2,110	7,053	25,741	36,065	32	35	Orthoclase, biotite, muscovite
1208	"							
1210	"							

universally low in nitrogen and phosphoric acid, and in the southeastern part of the State, also in potash. The potash content is much higher in the northern part of the Coastal Plain section; especially is this true north-east of Albemarle Sound. The soil of the Edgecombe Farm is between these two extremes approaching the lower rather than the high potash content. These light sandy soils are also deficient in lime. This deficiency is noticeable in growing legume crops. Bacteriological investigations show this soil to be very deficient in beneficial bacterial life.

PLATS.

The plats at the Edgecombe Farm on which the experiments were conducted are embraced in Fields A and B. The farm on which all the plats are located has been in cultivation for a good many years. The experiments were started on Field A in 1903 and on Field B in 1905. The plats in Field A were laid off in three parallel series of thirteen plats each with a turn row or driveway between each series. The plats are one-tenth acre in size, with an unfertilized space between them sufficient for one row and a four-foot unfertilized space at the end of the rows. Plats, 1, 2 and 3 of the second series and 1, 2, 3, 4, 5, 6, 7 and 8 of the third series of this field are somewhat inferior in fertility naturally to the other plats of the field due to surface washings.

The plats on Field B were laid off similarly to those of Field A, except the plats of the third series were one-twentieth acre in size. Another difference was that in field B provision was made for two rows between plats instead of one, as in Field A and these extra rows were fertilized like the plat nearest to them, but were not

ES OF CECIL CLAY LOAM, IREDELL TEST FARM.

rals in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
Altered biotite, muscovite, zircon	Epidote, plagioclase, hornblende, rutile, zircon, magnetite, sillimanite, chlorite microcline	Chlorite, plagioclase, rutile, magnetite, epidote	Minerals show signs of having been badly leached. Much quartz carrying infiltrated iron oxide. Biotite shows alteration especially in the silt. Orthoclase badly weathered.
Weathered orthoclase, muscovite	Epidote, hornblende, chlorite, plagioclase, magnetite, rutile zircon. Included apatite	Epidote, plagioclase, chlorite, magnetite, rutile, zircon	Much quartz carrying infiltrated iron oxide. More orthoclase and muscovite than in soil. Biotite badly altered.

harvested and weighed with the plat. Bur clover was sowed in Field B at the last cultivation of corn in 1908 and of cotton in 1909, but as bur clover failed in 1909 the plats were seeded to crimson clover early in November.

Field A.—The plats were used for fertilizer experiments with cotton in 1903, '04, '06, '08, for fertilizer experiments with corn in 1905, '07, '09. In the case of the two crops the same plan or system of fertilization was followed. By this is meant that, plat 8 in all cases received only nitrogen and potash, plat 9 only phosphoric acid and potash, and so on, though the quantities actually applied varied with the two crops. The fertilization of the cotton plats was based on a normal application of 400 pounds per acre of a mixture containing 7 per cent available phosphoric acid and 2½ per cent each of nitrogen and potash. The fertilization for corn was on a basis of 300 pounds per acre of a mixture containing 7 per cent available phosphoric acid, 3 per cent nitrogen, and 1½ per cent potash.

Field B.—These plats were used for fertilizer experiments with corn in 1906 and 1908 and for fertilization experiments with cotton in 1905, '07, '09.

Fertilizer Materials Used.

N equals nitrogen at the rate of 10 pounds per acre, or 77 pounds of 13 per cent dried blood;
P equals phosphoric acid at the rate of 28 pounds per acre, or 200 pounds of 14 per cent acid phosphate;
K equals potash at the rate of 10 pounds per acre, or at the rate of 50 pounds 20 per cent manure salt;
L equals lime at the rate of 500 pounds rock or 1,000 pounds slaked lime per acre.

TABLE 11—RESULTS OF FERTILZER EXPERIMENTS WITH COTTON; EFFECT OF NITROGEN, PHOSPHORIC ACID AND POTASH IN DIFFERENT COMBINATIONS; LIME ALONE, AND LIME IN ADDITION TO A COMPLETE FERTILIZER ON FIELD A EDGECOMBE TEST FARM.

Number of Plat	Fertilizer Application per Acre	Pounds of Nitrogen (N) per Acre	Pounds of Phosphoric Acid (P_2O_5) per Acre	Pounds of Potash (K_2O) per Acre	Results in Field A in 1903, '04, '06 and '08 Yield in Seed Cotton in Pounds per Acre 1903	1904	1905	1906	1907	1908	1909	Average Annual Yields of Seed Cotton in Pounds per Acre	Increase in Pounds of Seed Cotton Due to Fertilizer	Value of Increase at 4.5 Cents per Pound	Cost of Fertilizer per Acre	Value of Average Annual Increase Over Cost of Fertilizer
7	Unfertilized O	------	------	------	1,215	1,380	--------	900	--------	625	--------	1,030	------	$------	$----	$----
8	77 lbs. 13% Blood N 50 lbs. 20% Manure Salt K	10 ------	------ ------	------ 10	1,410	1,370	--------	1,050	--------	1,030	--------	1,215	185	8.33	2.81	5.52
9	200 lbs. 14% Acid Phosphate P 50 lbs. 20% Manure Salt K	------ ------	28 ------	------ 10	1,245	1,185	--------	940	--------	935	--------	1,078	46	2.07	1.90	0.17
10	77 lbs. 13% Blood N 200 lbs. 14% Acid Phosphate P 50 lbs. 20% Manure Salt K	10 ------ ------	------ 28 ------	------ ------ 10	1,220	1,343	--------	1,140	--------	1,070	--------	1,193	163	7.34	4.21	3.13
10^3	77 lbs. 13% Blood N 200 lbs. 14% Acid Phospahte P	10 ------	------ 28	------ ------	1,358	1,323	--------	990	--------	760	--------	1,108	—9	—.41	3.71	—4.12
8^3	Unfertilized O	------	------	------	1,248	1,328	--------	990	--------	900	--------	1,117	------	------	------	------
6^3	500 lbs. Unslaked Lime every 4th year L	------	------	------	1,245	1,240	--------	960	--------	800	--------	1,061	—56	—2.52	0.63	3.15
7^3	77 lbs 13% Blood N 200 lbs. 14% Acid Phosphate P 50 lbs. 20% Manure Salt K 500 lbs. Unslaked Lime every 4th year L	10 ------ ------ ------	------ 28 ------ ------	------ ------ 10 ------	1,568	1,586	--------	1,320	--------	1,290	--------	1,441	324	14.58	4.84	9.74
8^3	Unfertilized O	------	------	------	1,248	1,328	--------	990	--------	900	--------	1,117	------	------	------	------

RESULTS IN FIELD B IN 1905, '07 AND '09.

	77 lbs. 13% Blood........N	10	------	------												
8	50 lbs. 20% Manure Salt........K	------	------	10	--------	--------	1,443	--------	1,004	--------	730	1,059	630	$28.35	$2.81	$25.54
	200 lbs. 14% Acid Phosphate........P	------	28	------												
9	50 lbs. 20% Manure Salt........K	------	------	10	--------	--------	1,273	--------	637	--------	710	873	444	19.98	1.90	18.08
	77 lbs. 13% Blood........N	10	------	------												
10	200 lbs. 14% Acid Phosphate........P	------	28	------	--------	--------	1,080	--------	690	--------	380	717	288	12.96	3.71	9.25
	77 lbs. 13% Blood........N	10	------	------												
11	200 lbs. 14% Acid Phosphate........P	------	28	------	--------	--------	1,455	--------	861	--------	750	1,022	593	26.69	4.21	22.48
	50 lbs. Manure Salt........K	------	------	10												
13	Unfertilized........	------	------	------	--------	--------	630	--------	357	--------	300	429	------	--------	------	------
1[3]	Unfertilized........	------	------	------	--------	--------	545	--------	270	--------	60	292	------	--------	------	------
5[3]	500 lbs Unslaked Lime every 4th year...L	------	------	------	--------	--------	820	--------	600	--------	110	510	218	9.81	0.63	9.18
	77 lbs 13% Blood........N	10	------	------												
	200 lbs. 14% Acid Phosphate........P	------	28	------												
6[3]	50 lbs. 20% Manure Salt........K	------	------	10	--------	--------	1,265	--------	996	--------	810	1,024	732	32.94	4.84	28.10
	500 lbs. Unslaked Lime........L	------	------	------												

The following average prices which fairly represent the cost of the several materials to the farmer for the period under experimentation have been assumed for the materials used:

14 per cent. Acid Phosphate	$14.00
13 per cent. Dried Blood	60.00
14.8 per cent. Nitrate of Soda	50.00
20 per cent. Manure Salt	20.00
Rock Lime	10.00

The following table gives the results of fertilization for cotton on Fields A and B covering a period of seven years.

Nitrogen and phosphoric acid, N P (Plats 10^3 and 10) gave increased yields over the unfertilized plats four of the seven years in Field A being 9 pounds; for four years on Field B an average loss of 288 pounds, or an average increase annually for seven years in the two fields of 167 pounds, worth $3.81 over the cost of fertilizer.

Nitrogen and Potash, N K (Plats 8 and 8). The application of nitrogen and potash combined gave larger increased yields for all seven years except one. The average increase for the seven years was greater than that given by any of the other applications except complete fertilizer and lime. The average profit from this application was $14.11 per acre.

Phosphoric acid and Potash, P K (Plats 9 and 9). Gave a large average annual increase for the three years Field A, 46 pounds, but for the four years on Field B the average increase was 444 pounds. This gives an annual increase on the two fields of 217 pounds, worth $9.81, which is $7.87 more than the cost of the fertilizer.

Phosphoric Acid, Potash and Nitrogen, N P K, (Plats 10 and 11). These materials combined in a complete fertilizer gave average increased yields in both fields. The average annual increased yields for the four

TABLE 12—MINERALOGICAL AND CHEMICAL ANALYSES OF

Laboratory Number	Depth to Which Sample Was Taken	POUNDS OF TOTAL PLANT FOOD CONSTITUENTS PER ACRE Surface, 6 2-3 inches----2,000,000 lbs. Subsoil, 28 inches-------8,000,000 lbs.				Minerals Other than Quartz in		Abundant Minerals
		N	P_2O_5	K_2O	CaO	Sand	Silt	Sand
Soil	*Average of 3 samples.* *Inches*					*Percent.*	*Percent.*	
1239 1243 1245	0– 8	853	953	3,087	3,220	5 to 7	8 to 10	None.
Subsoil	*Average of 3 samples.* *Inches*							
1240 1246 1254	18–36	1,360	1,573	11,453	8,880	5 to 7	8 to 10	None.

years on Field A was 163 pounds of seed cotton; and for three years on Field B, 593 pounds; or an average increase per acre for the seven years of 348 pounds, worth $11.45 over the cost of fertilizer.

Lime, L. (Plats 6^3 and 5^3). For the four years on Field A the lime plat showed an average annual loss of 56 pounds of seed cotton, representing a financial loss of $3.15. On field B however, this material gave an increase each of the three years, averaging 218 pounds more than the unfertilized plat, and a profit of $9.18. As an average of these two apparently contradictory results lime gave an average of 62 pounds representing a profit of $2.16.

Lime and complete fertilizer, N P K L, (Plats 7^3 and 6^3). With the exception of the year 1905 on Field B lime in combination with the three fertilizer constituents gave a larger yield of cotton than did complete fertilizer without the lime. The average yield for the seven years from this treatment was 142 pounds greater than for complete fertilizer without lime. The profit, $17.62, is greater than that from any of the other fertilizer combinations.

Taking the experiments as a whole, the average results show that:

The combination of nitrogen and phosphoric acid gave the smallest increase and also the least profit.

That nitrogen and potash gave an average yield of 209 pounds more seed cotton than did the nitrogen and phosphoric acid treatment, with a profit of $14.11.

Phosphoric acid and potash gave a slightly greater yield than nitrogen and phosphoric acid, but not nearly as great as nitrogen and potash.

Nitrogen added to phosphoric acid and potash making a complete fertilizer, increased the yield 131 pounds, and gave an additional profit of $3.58.

The results from lime while contradictory on the two fields, show a

NORFOLK FINE SANDY LOAM—EDGECOMBE TEST FARM.

Other than Quartz in	Less Abundant Minerals in		Remarks
Silt	Sand	Silt	
None.	Orthoclase, weathered and fresh, microcline, epidote, zircon, magnetite, chlorite, muscovite, hornblende	Orthoclase, microcline, epidote, chlorite, chloritized biotite	Potash accurs as felspars mainly, only trace of muscovite, and chloritized biotite. Lime is as epidote, almost entirely. Very little hornblende present. Quartz badly worn.
None.	Orthoclase, microcline, epidote, zircon, chlorite, magnetite diatoms	Orthoclase, microcline, epidote, zircon, chlorite, muscovite, hornblende	Very little difference between soil and subsoil in mineralogical composition. Slightly more micas in subsoil.

slight average increase and a profit of $2.16. In addition to complete fertilizer, lime shows an increase of 251 pounds of seed cotton, and its application here was at a profit of $6.17, and for the complete application—LNPK, the profit was $17.62.

The main increase yields and profits came from nitrogen and potash. On the whole, practically no beneficial effect was seen from the application of phosphoric acid. The application of lime was in general, accompanied with some profit.

Table 12 gives the average mineralogical and chemical composition of three samples of soil taken from the Edgecombe Farm.

The chemical analyses show that the soil from this farm is low in nitrogen and phosphoric acid, and compared to most of the Piedmont and Mountain soils, low in potash and lime. The mineralogical analyses show that the supply of potash is held mainly in the felspars; there being only a trace of muscovite in the sands and little more in the silt separates. What biotite found in the silt has been altered for the most part. Much of the orthoclase found here has been weathered, but microcline presents pure clean faces and sharp edges showing that little decomposition has taken place. Though the chemical analyses show that there is about 3,000 pounds of potash compounds per acre in this soil, the field results for seven years indicate that this element can be applied with profit. This fact bears out somewhat the conclusions drawn by other investigators as to the availability of potash when held in the form of felspar. In this soil the greater part of the orthoclase shows such marked signs of chemical decomposition, that it is reasonable to assume that microcline furnishes the greater part of the potash here.

The Mountain and Piedmont soils, experimented with, have the micas as their principal source of potash. In these soils the amount of organic matter is little higher than that from the Edgecombe Farm. It would not seem probable that the difference in the potash requirements are due to the amount of decaying organic matter liberating more potash in the Piedmont and Mountain soils and not so in this soil from the Coastal Plain. The difference must be due to the way the potash is held in these soils.

Lime is supplied to the soil from the Edgecombe Farm almost entirely as epidote, there being only a trace of hornblende, and no plagioclase felspar present. The field results obtained on this farm indicate that lime can be used here at a profit, whereas the chemical analyses show that the surface soil to a depth of 6⅔ inches contains some 3,000 pounds of this material.

In this soil the supply of phosphoric acid is very low, that which is present is in other forms than the mineral apatite. Most careful examinations have failed to show this mineral in a single instance.

SUMMARY

The field results obtained on experimental farms show that there is a close relation between the chemical and mineralogical composition and the fertilizer requirements of the soils under experiment. The chemical analyses are of value in determining the total amount of the various elements of plant food which the soil contains, and the mineralogical analyses supplementing the chemical analyses, show to a great extent in what way these elements are combined.

The soils of the Mountain and Piedmont sections of the State are, as a rule, better supplied with potash, lime, and phosphoric acid than are those of the Coastal Plain.

The micas furnish to a much larger extent the potash supply in the former two sections than they do in the latter. In a great many of the Mountain soils muscovite and biotite are the main sources of potash, and in a majority of these soils the biotite content is well preserved. The potash felspars are much more abundant in the soils of the Piedmont Plateau than they are in the Mountain section, however, the micas furnish much of the potash for these soils. In the Coastal Plain soils, orthoclase and microcline supply most of this material, and it is on these latter soils that the greatest response is secured from the use of potash fertilizers, as shown by the field results thus far published.

The phosphoric acid content of most North Carolina soils is low. Much of this element of plant food is found as apatite included in quartz and other minerals. In this form it is doubtful if the plant can draw its supply of phosphoric acid, certainly not for many years to come. The soils of the Coastal Plain carry their main supply of phosphoric acid in other forms than apatite, for in very few instances has this mineral been encountered in soils from this section.

Lime in the Coastal Plain soils is for the most part in a less available form for crops than much of that found in the sections higher up in the State. The former soils derive their main supply of lime from epidote. In the Piedmont and Mountain portions hornblende and the plagioclase felspars are found in larger quantities than in the Eastern section. The amount of the plagioclases has never been large, except in the soils of the Iredell series. There they are found in some quantity.

In the mineralogical composition as a rule there is little difference between the soil and subsoil. This may be due to the depth to which the samples were taken.

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NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE
AND THE
COLLEGE OF AGRICULTURE AND MECHANIC ARTS

RALEIGH AND WEST RALEIGH

BREEDING ROTUNDIFOLIA GRAPES

A STUDY OF TRANSMISSION OF CHARACTER

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BREEDING ROTUNDIFOLIA GRAPES

By F. C. Reimer and L. R. Detjen.

INTRODUCTION.

This is a preliminary report on the grape breeding experiments that are being conducted by the North Carolina Experiment Station. Many of the hybrids that have been produced have not yet fruited, and it will be several years before the work as a whole is completed. But grape growers and nursery men throughout the South have become very much interested in these experiments since Bulletins 201 and 209 of this Experiment Station were published; and they are anxiously awaiting the results of our investigations. It will also be seen from the discussion which follows that there is great need for extensive grape breeding in all sections of the South. It is thought best, therefore, not to delay any longer the publication of the results thus far obtained.

While the work has not yet been completed, it should be said that some of the fundamental principles, pertaining to the breeding of this species, have been determined. The results which are discussed in this bulletin should enable breeders to proceed more intelligently in the future, and with some assurance of obtaining definite results. It is hoped that this publication will induce individuals in various sections of the South to take up that phase of the work which has as its special object the production of new and better varieties.

The authors wish to express their appreciation to Professor J. P. Pillsbury for his many helpful suggestions.

Also to J. W. Harden, J. T. Holloway, H. Mahler, A. G. Spingler, S. W. Brewer, J. R. Chamberlain, and Dr. D. H. Hill, for the generous use of their grape vines in connection with these breeding experiments.

IMPORTANCE OF ROTUNDIFOLIA GRAPES IN THE SOUTH.

Vitis rotundifolia, commonly called Muscadine, is the leading grape in the South. That it is admirably adapted to the climatic and soil conditions of this region is shown by the fact that it is more extensively grown here than all other grapes combined. The chief reason for this is that it is native to this section, growing wild in great abundance in the Coastal region from southern Delaware to central Florida, and westward to central Texas.

That this grape is so well adapted to the poor sandy soils of the Coastal region, where comparatively few other fruits succeed is fortunate from an economic point of view, for under these severe conditions it grows and bears well, and is especially long lived.

It is remarkably resistant to fungous diseases, even in a section where such diseases are very prevalent, and where the leading varieties of the labrusca grapes are severely injured. It is true that Black Rot (*Guignardia bidwellii*) sometimes severely attacks the blossoms and the leaves of the Scuppernong, but the injury done cannot be compared with that which this disease inflicts on such varieties as Concord, Niagara, and Delaware.

The varieties of this species are also remarkably free from insect attacks. It is well known that this species is more resistant to the dreaded root louse, known as Phylloxera, than any other American species of grape; in fact investigations by European experts have shown that it is so seldom and so slightly attacked by this insect that the injury caused is practically negligible. So far as we can ascertain the Cane Borer and the Root-worm have never attacked this species of grape.

One of the most valuable characters of this grape is its tardy blooming season in the spring of the year. By this means very few, if any, of the flowers are nipped by the much dreaded late spring frosts. In central North Carolina growth does not begin until all danger of damaging frosts is passed, and the first blossoms do not open until the latter part of May. As far as we can ascertain, no injury to this grape has ever been caused by late spring frosts, even during the most unfavorable seasons on record. The importance of this can be appreciated when we realize that many fruits, including the important labrusca and their hybrid grapes, commence growth, and bloom, very early in the warmer sections of the South, and are often severely injured by the late frosts.

Another valuable character of plants of this species is their remarkable longevity. No cultivated variety of the other American species of grapes can compare with them in this respect. Some of the Scuppernong vines still living and bearing good crops of fruit were undoubtedly planted years before any of the leading varieties of *Vitis labrusca* were brought into cultivation. In Eastern North Carolina can be found many Scuppernong vines with trunks more than a foot in diameter; and occasionally one more than two feet in diameter.

The period of ripening of the various varieties of this species is a long one, lasting from three to four weeks. By planting some of the very earliest, mid-season, and late varieties fresh fruit can be had in Eastern North Carolina from August until early November. This is of considerable importance for the home fruit garden, since at that time of the year, in this region, there is a scarcity of other fruits. It is also of importance to the wine maker to have the fruit of the later varieties at a season when the hottest weather of the year is over. Where there is a scarcity of labor this long ripening season is of value since it gives plenty of time for gathering the fruit.

NEED OF IMPROVEMENT.

In some respects this rotundifolia species is the most unique of American grapes. Undoubtedly it possesses the most remarkable combinations of exceptionally good characters and extremely bad ones that can be found in any one species of grape. To emphasize the need and importance of breeding and improvement work with this species, attention may be called to some of its most grievous defects.

One of the most undesirable characters that is found in almost all of the important varieties is the shelling of the berries from the clusters as soon as ripe. A slight wind, shaking the vine at picking, or even the weight of the fruit itself, will cause the berries to drop. This is notably true of the Scuppernong and the Thomas, two of the most desirable varieties of this species. It is a character that practically precludes the shipping of the fruit to market. Any one who has attempted to ship rotundifolia grapes any distance to market, knows that they usually arrive in a very bad condition. Most of the berries have separated from the clusters, and the package presents a mixture of berries and bare stems, the appearance of which is not very tempting to the buyer. The whole matter becomes more complicated by the frequent breaking of the skin of the berry at the point of attachment when separating from the pedicel. The juice begins to ooze out at this point. fermentation sets in, and the fruit soon develops a disagreeably sour flavor. The Flowers and the Flowers Improved are better in this respect, but these two varieties at best, are inferior in quality.

The marketing of these grapes is further complicated by the irregularity of ripening of the berries on the same cluster. Often some of the berries are ripe and ready to pick while the others are too green or immature to gather. If the berries are not picked when ripe they will either fall off or they will shrivel on the cluster, which renders them unfit for the market. It can be readily understood that to place such fruit on the market is practically useless.

As soon as this grape is picked from the vine, its quality begins to deteriorate. And this deterioration proceeds with such rapidity that grape connoisseurs make the statement that the fruit of the Scuppernong is not as good five hours after it is picked from the vine as it is immediately after picking.

This poor keeping quality, coupled with the frequent breaking of the skin at picking, which prepares the way for rapid fermentation, precludes the successful shipping of the grape to any great distance.

It is sometimes stated that this poor keeping and shipping quality is not of great moment, since most of the fruit that now goes to market is used for wine making. This idea is certainly erroneous, for the best wine experts are agreed that the fruit of the Scuppernong grape that is to be used for wine making, for best results should be sound. Whenever the skin of the berry has been broken, and fermentation has been active, even for a day or two, the quality of the wine is much impaired.

Another defect of this species is the very small and variable size of the fruit clusters. The number of berries of the cluster varies from one to about twenty-five. Only in very rare instances are there more than twenty, and most clusters have only from three to ten berries (See Figs. 1 and 2).

Such small and variable clusters are objectionable from several standpoints. They are so small that they do not appeal to anyone who is accustomed to the large clusters of the European grapes, or such American varieties as the Concord, Niagara, Herbemont, and others. They do not have a uniform appearance on the market; and it is well known that uniformity of product, especially as to size, is one of the cardinal principles in the marketing of fruit.

All the cultivated varieties of this species are self sterile; that is, they are incapable of setting and developing fruit from their own pollen (See Fig. 3). Furthermore, the pollen of all of the present cultivated varieties is worthless, hence it is impossible for one variety to cross-fertilize another variety. The only way that normal fruit can develop on

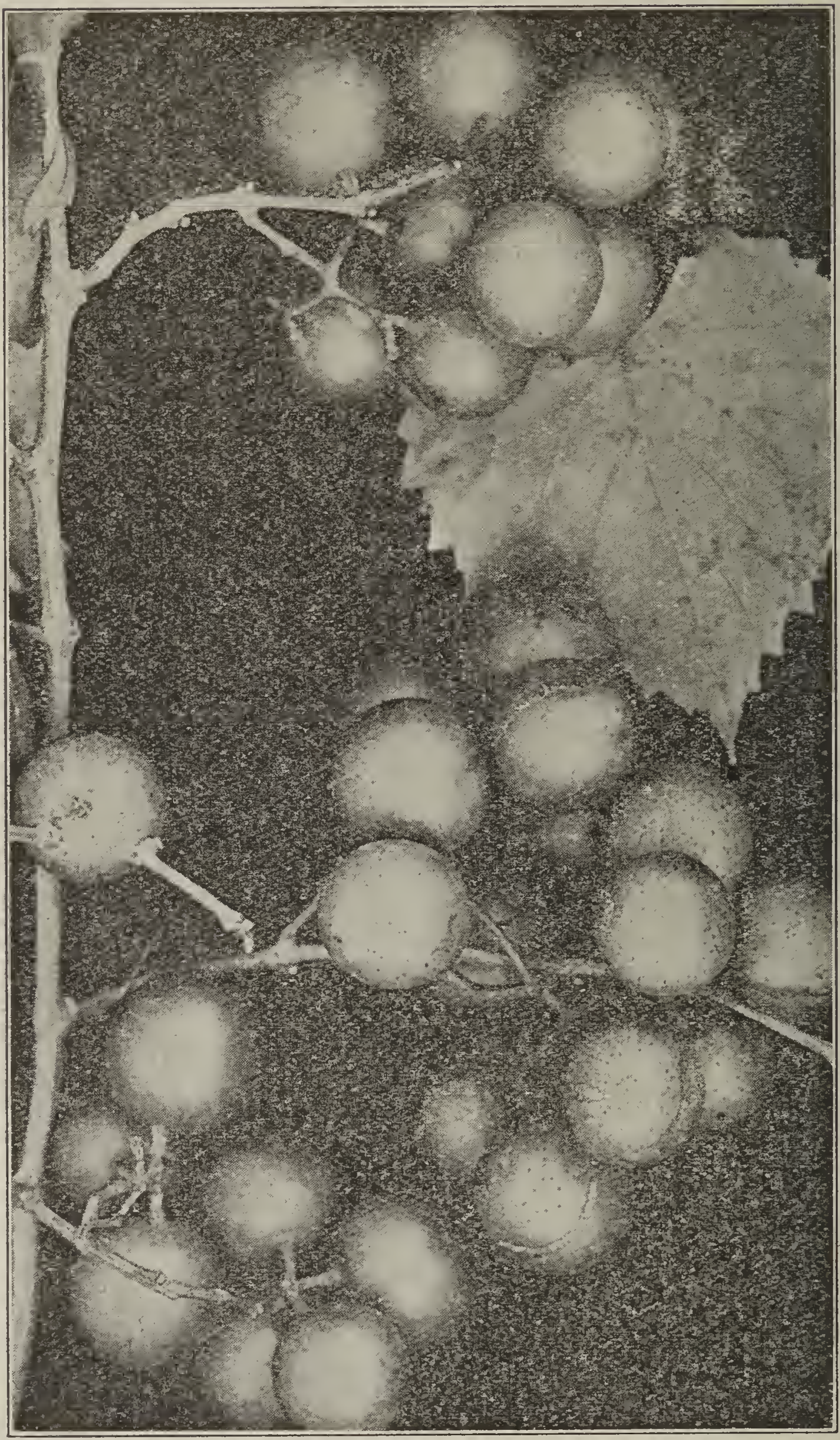

Fig. 1.—Fruit cluster of Vitis rotundifolia, variety Scuppernong (slightly reduced).

these varieties is by cross-pollination with some male vine. This means that male vines (which do not produce any fruit) must be maintained near, or more preferably in the vineyard. In large plantings it is necessary to place such male vines in various parts of the vineyard to obtain satisfactory results; or to top-graft some of the canes of the bearing plants with scions from the male vines. If the varieties were self-fertile, the space and the attention required by the male vines, could be used to much better advantage. Furthermore, the planting and the maintaining of male vines in the vineyard does not always insure satisfactory crops. During rainy seasons, when much of the pollen from male vines is washed away and lost, and when insects are not very active, the crops produced are frequently unsatisfactory. If it were not for the unusually long blooming season of these varieties, many times lasting three to four weeks, a large crop would rarely ever be produced. This was well demonstrated by the writers in their extensive self-sterility studies of these grapes (Bul. 209, N. C. Agr. Exp. Station). With the most careful and painstaking cross-pollination work seldom more than half of the blossoms on a cluster would set fruit.

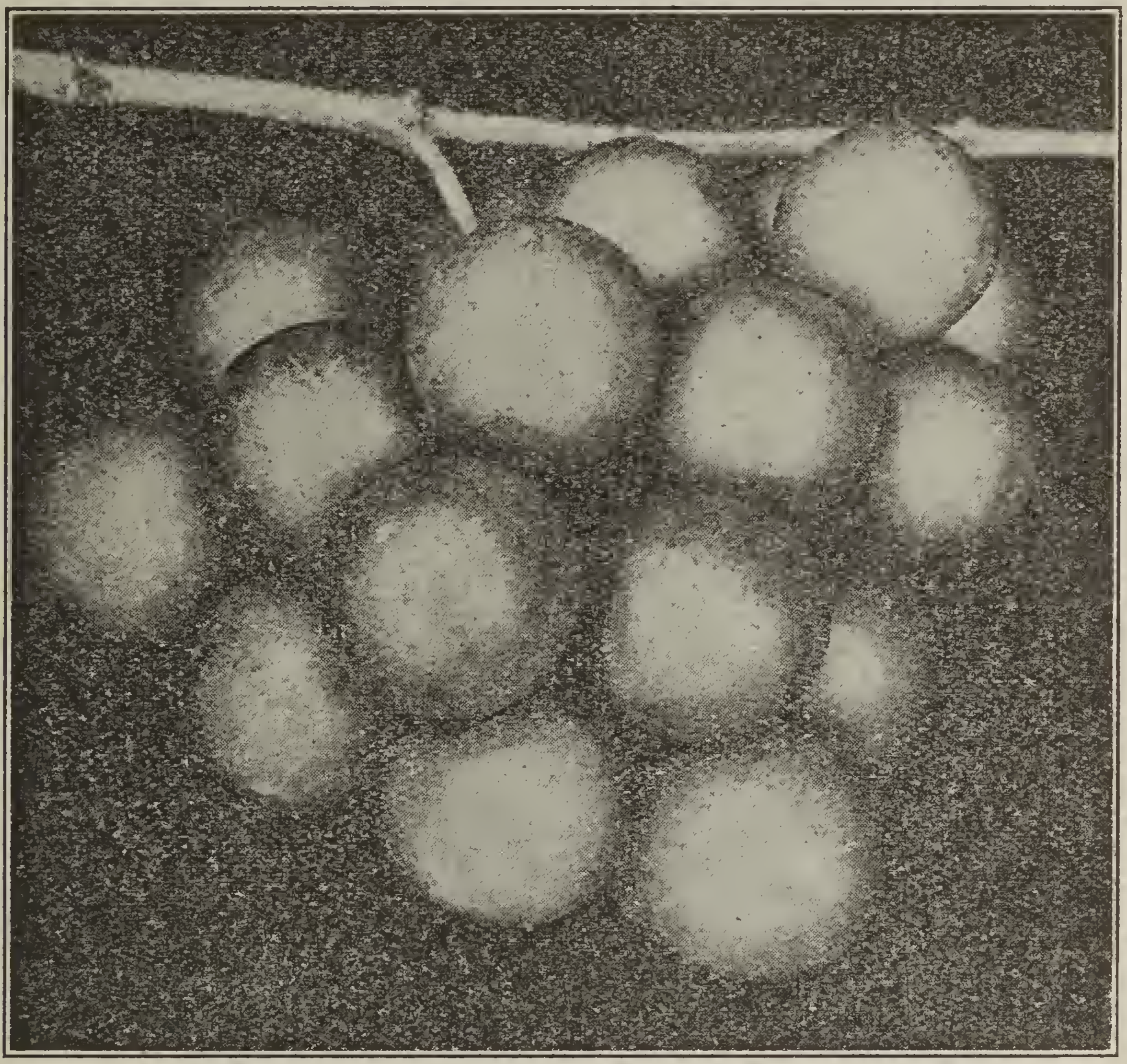

FIG. 2.—Very large fruit cluster of Scuppernong (natural size).

Our number of good varieties of rotundifolia grapes is still too small. When we consider the fact that nurserymen are now advertising only about six varieties, all of which originated under similar conditions, we can readily comprehend that it is a very unsatisfactory and a very meagre list from which to select. That varieties, all of which come

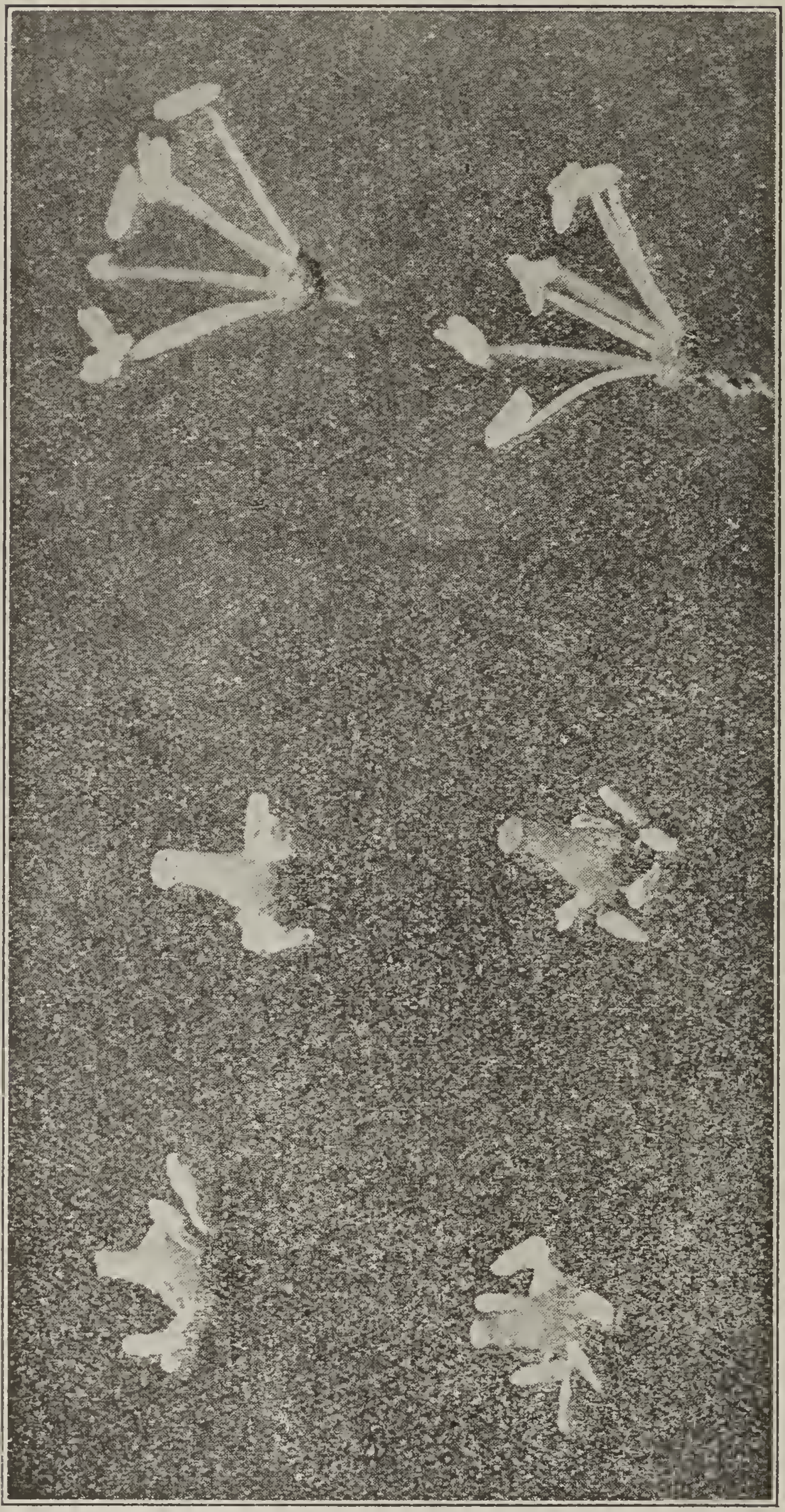

FIG. 3.—Flowers of Vitis rotundifolia. Male flowers on the right; pistillate in the center; Scuppernong flowers on the left. (Magnified two diameters.)

from one locality and one type of soil, will not be equally well adapted to the Carolinas, to central Florida, the heavy soils of Alabama, the limestone soils of Mississippi, and the camparatively dry climate of central Texas, is only reasonable to assume. Varieties are needed which will be adapted to each of these different environments. Here is a field for splendid breeding work.

We need more white varieties. At the present time the Scuppernong is the only white variety in general cultivation. This variey originated in northeastern North Carolina on sandy loam soil; hence it is not equally satisfactory throughout the entire Southern States. Yet the leading wine manufacturers do not wish any of the dark varieties for wine making. They find that the light-colored wines, made from the white rotundifolia grapes are distinctive in color and flavor, and are much more popular and profitable than those made from the dark varieties. It should also be stated that the wineries at the present time constitute the leading market for these grapes. Hence, the importance of originating more white fruiting varieties, which may be successfully grown in the different climates and on the various types of soils.

It is also very evident that we need more red fruiting varieties, for only one red variety is being offered for sale by the nurserymen. Four other red varieties, Lady James, Brown, Latham, and Luola, have been named and locally planted; but still the list somehow is very unsatisfactory. Some of the red varieties of rotundifolia grapes produce fruit with a shade of a beautiful wine-red, that is very pleasing to the eye, and certainly would attract attention on the market. But the fruits of these varieties are small in size and are very poor shippers. It is very important, therefore, that we originate other varieties that possess this attractive color, and which will have large clusters and large berries, and will ship well.

Another objectionable feature of most all of the varieties is the large seeds which their fruits contain. In this respect this is the worst of all American species of grapes, for the seeds will average even larger than those of Vitis labrusca, and those of Vitis lincicumii. These large seeds are undesirable in grapes for the table, or, in grapes for the manufacture of wine.

Other objectionable features are the thick, leathery skin, and the low sugar content in most varieties, coupled with a tough, coarse, and often a stringy pulp.

EARLY ATTEMPTS TO IMPROVE THESE VARIETIES.

The undesirable characters of these grapes were very apparent even to the early grape growers, as is indicated by their attempts to originate better varieties. The writers have made a careful study of all of the available literature on this early breeding work, and the following extracts from this will be given to show what was attempted and accomplished by these early experimenters.

Quotations From Early Experimenters.

One of the leading spirits early interested in the Scuppernong grape was J. Van Buren, of Clarksville, Ga. In 1868 Mr. Van Buren published the only book that has ever been published on the Scuppernong grape. On page 19 of this book he writes: "Seedlings of the Scuppernong have but little uniformity in appearance; some are red, others brown or nearly black, and others again green and yellow." On page 20 he again states: "The seedlings begin to bear fruit the third or fourth year; it is to these we are to look for great improvement in this fruit. Many, doubtless, will be inferior to the parents, while some will be equal and others superior in size and flavor. Bestow the care and attention to cultivation and raising seedlings from this fruit that has been expended upon the strawberry and we may with confidence expect to have vines producing berries as large as hen's eggs or even larger. To do this we have but to follow Van Mons, the great pear grower, of Belgium, who says, 'sow, sow, keep sowing seeds,' and improvement is sure to follow." On page 23 he continues: "To those who are dissatised with the merits of the Scuppernong we would again urge to sow its seeds, and beyond all question you will sooner or later get a grape far superior to it in size and flavor, but not in exemption from disease, or more productive, or easily cultivated."

Mr. Van Buren began such work of raising seedlings, and in an article published on page 69 of the *Southern Cultivator* for 1872 he reports the results of this work: "In the fall of 1867 we sowed a quantity of the seeds of the Scuppernong and the subsequent year raised about 2,000 plants, which grew to the height of some two feet; amongst this number we found but one plant that would produce a white grape. * * * In the fall of 1868 we again sowed about the like quantity of seeds from the Scuppernong and amongst some 2,000 plants failed to get a single white grape; in the fall of 1869 we again sowed about the same quantity and kind of seeds as before, from which we got three plants that would produce white grapes. * * * In the fall of 1869 we sowed eight seeds taken from the white variety above described, it being the second remove or generation from the wild type of this class of grapes. These eight seeds all grew last summer and we find three out of the eight to be white varieties."

Another early experimenter with this grape was Jno. McRae, of Camden County, S. C. On page 62 of the *American Farmer* for 1877 he writes as follows: "I have been amusing myself in growing seedlings of the Scuppernong. * * * I have fifteen or twenty which produced fruit last year; about one-half of the color of the parent; the other black. * * * I planted last year over 1,900 seeds; of which nearly all grew, and of these about 10 or 11 per cent had the color of the parent."

The most systematic breeding work of the early experimenters was attempted by Dr. Peter Wylie, of Chester, S. C. In the Report of the American Pomological Society for 1871 he writes as follows: "My experience will go far to establish the following facts, viz.: That we can not fertilize the Scuppernong with the pollen from any other species, or their hybrid varieties, or with male (staminate) hybrid Scuppernongs. Second, that we can impregnate the foreign (Vitis vinifera), with pollen from the suppernong producing thereby only male (staminate) plants, and imperfect hermaphrodite or pistillate plants, which bear no fruit. Third, we can not impregnate Labrusca, æstivales, cordifolia, or their hybrids, with foreign (Vitis vinifera) with pollen from

Scuppernong. Fourth, that we can fertilize both native and foreign and their hybrids, with male (staminate) hybrid Scuppernong pollen producing thereby prolific hybrid Scuppernong vines. Fifth, that we can fertilize those prolific hybrid Scuppernong plants with pollen from the hybrid male (staminate) Scuppernong vines, thereby giving more of the Scuppernong constitution to the progeny. I find that the seed of the prolific hybrid Scuppernongs grow and that you can impregnate other varieties with pollen from prolific hybrid Scuppernongs."

It is very unfortunate that we do not have more details regarding Dr. Wylie's work. The meaning of some of his statements is not entirely clear. Some of the assertions made by him in the foregoing discussion have been found by later investigators to be correct; while others are erroneous. The experiments of the writers and those of T. V. Munson have shown that the first and second propositions laid down by Dr. Wylie are not correct; while the third, fourth, and fifth, at least in part are correct.

RECENT EXPERIMENTS.

The late T. V. Munson, of Denison, Texas, from 1890 to 1900, did some excellent breeding work with the Rotundifolia grapes. His work was thorough and systematic. He demonstrated that Vitis rotundifolia will hybridize with such other species as Vitis munsoniana and Vitis linciicumii hybrids. By such hybridization he produced a number of varieties, of which the following are the best known: La Salle, San Jacinto, Sanalba, Sanmelaska, Sanmonta, and Sanrubra. At the present time, however, these varieties are of interest only to the plant breeder for they do not seem to be much if any, improved over our present cultivated pure rotundifolia varieties. It is to be regretted that this remarkable grape breeder did not extend his breeding work with this species of grape. His elaborate and valuable work with other species of grape indicates what he would have accomplished if he had extended his breeding work with the rotundifolia grapes.

The Viticultural Division of the United States Department of Agriculture has also commenced breeding work with the rotundifolia and munsoniana species of grapes. Some of the results of this work have been published in Bulletin No. 273, Bureau of Plant Industry, United States Department of Agriculture. Among their seedling grape vines two were found that are self-fertile. The production of valuable self-fertile varieties is one of the important things desired by breeders of this species of grapes.

BREEDING WORK OF THE NORTH CAROLINA EXPERIMENT STATION.

In 1908, as part evidence of the self-sterility of the Scuppernong and other rotundifolia grapes, our first handbred seeds were obtained; and since that time each season numerous seedlings from this and other varieties of rotundifolia were secured. The resulting seedlings were transplanted to nursery rows and carefully studied.

It should be stated that the weather conditions during this time have been favorable to this work. Parent vines that were used in these experiments have bloomed and produced fruit every year since the work was started.

As a rule, the seedlings have produced a good growth and practically all of the vines that were secured during the first three seasons have fruited; and the results of our observations are set forth in this publication.

Some of the earlier results of this work have already been published in Bulletin No. 209 of this Station, and a brief discussion will be found on page 31 of the Proceedings of the Seventh Annual Meeting of the Society for Horticultural Science.

Objects.

It has already been stated that there is great need of improvement in this species. That this was recognized even by the early grape growers is shown by their writings, and their attempts to improve the Scuppernong. Attention has also been called to the fact that comparatively little was accomplished by these early experiments. This was due to the fact that at that time nothing was known regarding the difficulties involved and the habits of this grape. The laws of inheritance in this species were not and could not be understood at that time for it was not known that those varieties were all self-sterile.

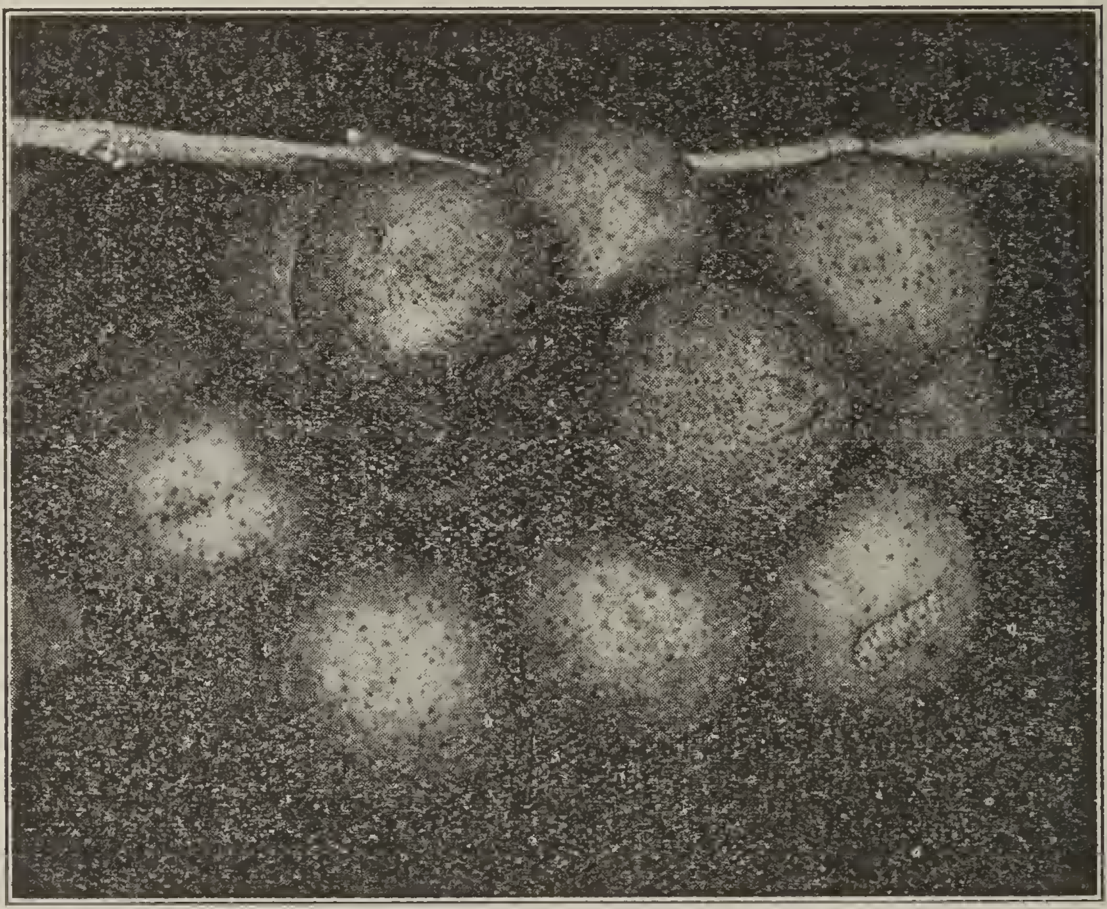

Fig. 4.—Fruit cluster of Scuppernong, showing the russeting (natural size).

The primary object, therefore, of our breeding work has been to make an exhaustive study of the laws of inheritance in this species; and to determine what the results would be, or what could be expected, when certain combinations were made in crossing. In brief our chief object has been to learn how to breed Rotundifolia grapes; and to lay a foundation for future breeding work that might be of value both to the breeder who studies principles, and to the grower who is simply breeding for improved varieties.

Varieties Used.

Nearly all of the leading varieties of the Rotundifolia grapes were used in these breeding experiments. The largest amount of work was done with the Scuppernong, since this is the most widely planted variety of this species, and it is the only white variety that is extensively cultivated. The black varieties used were James, Flowers, Memory and Smith; the only red varieties were Thomas and Latham.

Male Vines.

Special attention was given to the selection of the male vines that were used in our breeding experiments. These were of two groups: the light males, or those that correspond in color of the vine with the Scuppernong; and the dark males, or those that correspond in vine color with such varieties as James, Thomas, and Flowers.

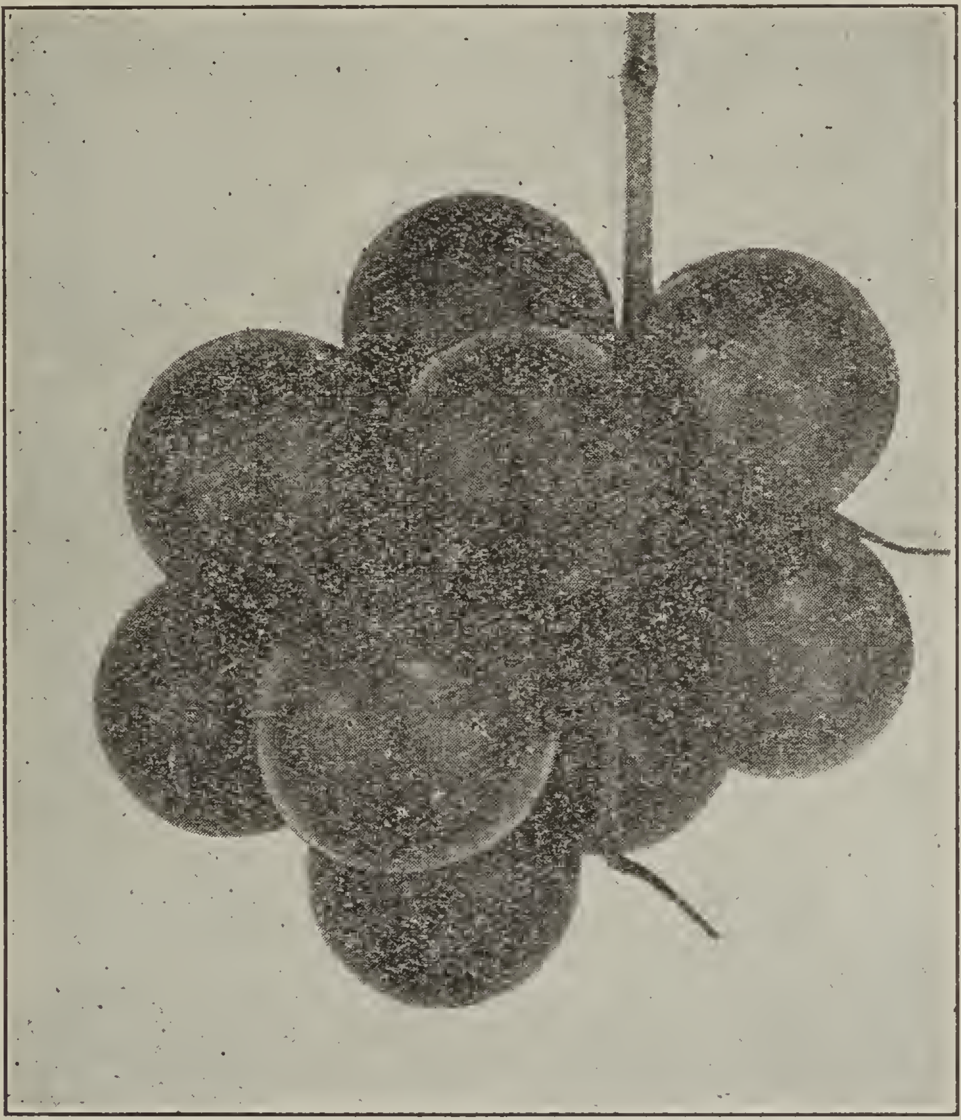

FIG. 5.—Fruit cluster of James (natural size).

The light males are distinguished by their light colored or greenish shoots, nodes and tendrils. Of this type one vine was selected which produced small flower clusters, and two that produced large flower clusters.

The dark male vines have dark, brown or reddish, colored shoots, nodes, and tendrils. All the vines selected of this type produced large flower clusters, and one of them produced the largest cluster of any male vine ever found in our work.

Methods.

In the work of crossing and of collecting the hybridized seeds, all necessary precautions were taken to avoid mistakes. The flower clusters to be cross-fertilized were securely covered with fine cloth bags, that were made especially for this work. This in most cases was done before any of the blossoms had opened, but where any had opened these were removed from the cluster before it was covered with the bag. In all the earlier work the flower clusters of the male vines were also covered before any of them had opened, and the pollen was collected from time to time as it was needed. In the later work this operation was facilitated by bringing canes with several flower clusters into the laboratory, placing them in water, and screening them from flies and other insects to prevent contamination of the various different lots. The pollen was collected from day to day as the flowers opened, and stored in glass test-tubes until it was needed. In our self-sterility studies we had already found that the pollen from the cultivated varieties is worthless and impotent, hence it was not necessary to remove any of the stamens or anthers from these varieties before applying the pollen from the male plants. This knowledge was to us of great moment, for it saved us much valuable time. The actual work of cross-pollination requires considerable time, for only a few flowers open on the cluster each day. It is therefore necessary to go over each lot of flowers about three times a week, until all of the flowers have opened, a period usually lasting from two to four weeks. During each operation the bags were carefully removed from the flower clusters, the pollen taken from the test-tubes with a camel's hair brush and applied to the stigmas of the flowers, and then the bags were replaced. Each cane was carefully labeled, indicating the cross made, and a corresponding record was kept in a note book. As soon as the fruit ripened in the fall it was collected, the seeds removed, dried, and stored. It was necessary to collect the ripening fruit at regular intervals of time for, as previously stated, the ripening season of this grape lasts several weeks. (See Figs. 4 to 9 inclusive.)

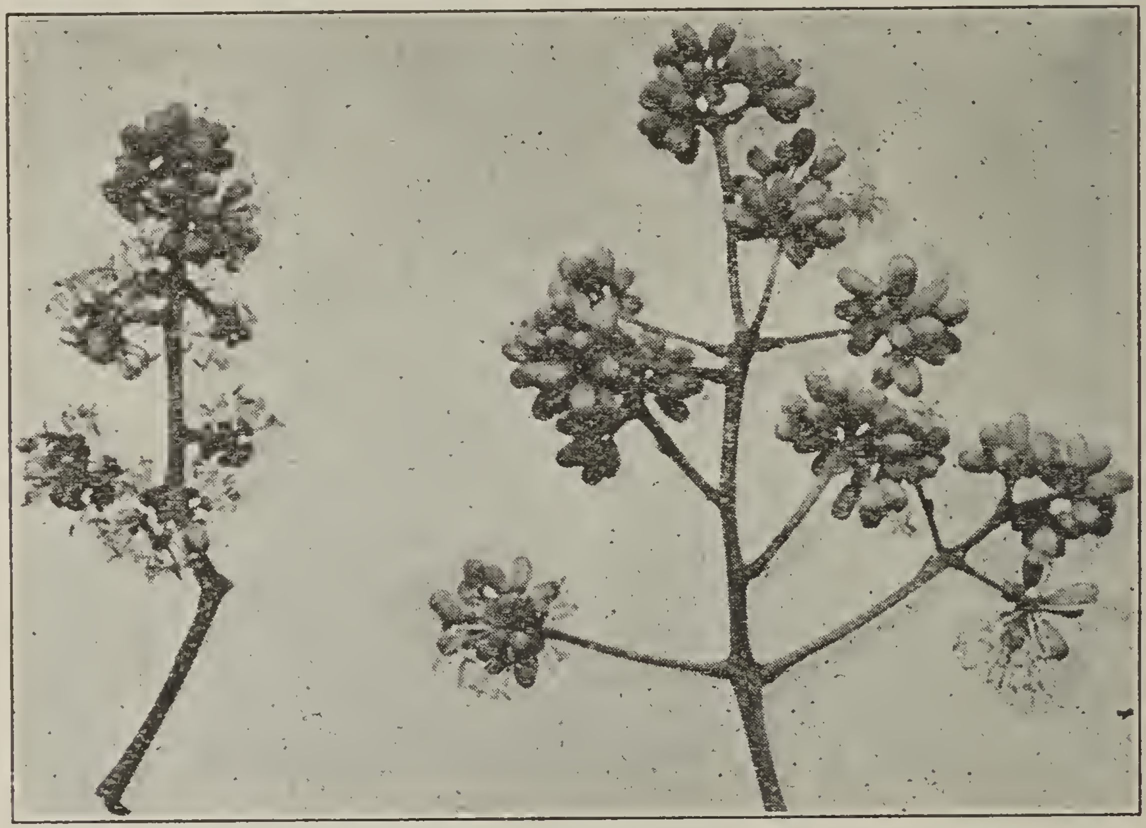
Fig. 6.—Flower clusters from male vines. Cluster on left from an average male vine; cluster on the right from an exceptionally good male vine.

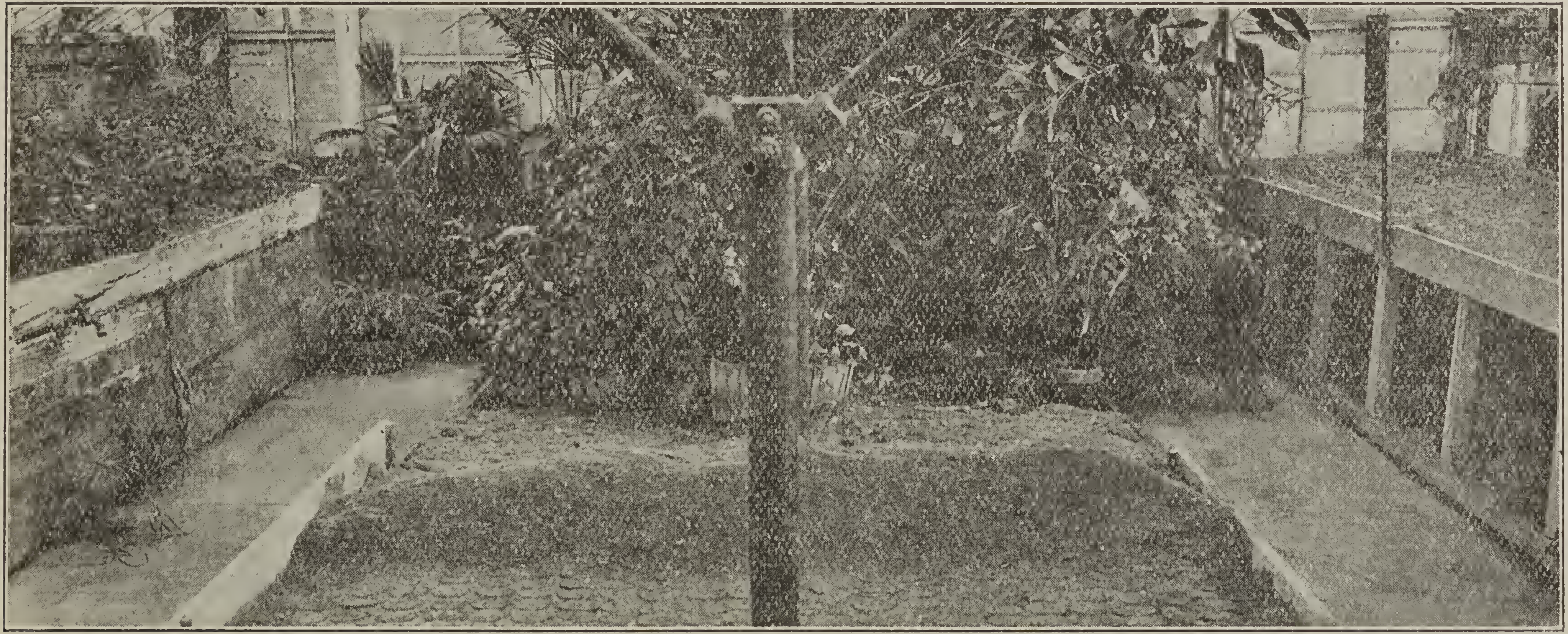

FIG. 7.—Three-inch flower pots plunged and planted to grape seeds. A dirt cover was used up to the time of germination of seeds to facilitate weeding and for maintaining a uniform degree of moisture in the soil.

After all the seed was harvested, it was planted in small flower pots. These were plunged in the green-house, and watered from time to time as occasion required. At about the middle of March the seedlings began to appear. These were left undisturbed, except for the forcing and weeding processes, until about the middle of July. As no more seeds seemed to germinate the plants were taken up and transplanted to the regular vine nursery. Here they grew rapidly and a careful study as to their behavior was begun.

Results and Discussions.

Sex of Hybrids.

In discussing the subject of sex it must be borne in mind, that one of the parents in every cross was a male vine. All the female vines that were used in this work, behave in reality simply as pistillate plants, for the pollen produced by them is absolutely impotent. It is to be regretted that many of the vines have not yet bloomed, otherwise it would be possible to give the sex of a much larger number of hybrids. However, enough have bloomed to indicate with a fair degree of accuracy, the proportion of male and female plants. The table below gives our observations on the distribution of sex in seedling Rotundifolia grape vines:

TABLE NO. 1.

Distribution of Sex in Rotundifolia Seedlings.

Scuppernong X Light Male No. 1	11 Males	8 females.
Scuppernong X Dark Male No. 1	329 males	307 females.
Scuppernong X Light Male No. 2	507 males	494 females.
James X Light Male No. 2	59 males	64 females.
Thomas X Light Male No. 2	30 males	33 females.
Total number of all the seedling vines	936 males	906 females.

It will be noted that slightly more than one-half of the seedling vines are males, and a little less than one-half are females. This corroborates observations made on many wild vines where the sexes seem to be about equally divided. In some places among the wild vines one sex seems to predominate, while in other places another; but the totals are practically equal. This is a provision of Nature to supply a male for every female vine.

No self-fertile seedlings so far have appeared among our hybrids. In 1910 the writers found a wild rotundifolia vine (Bul. 209, N. C. Agr. Exp. Sta.. p. 18.) which bears fruit and also long, erect stamens, which produce good, potent pollen like that from the male vines. There is little doubt that self-fertile rotundifolia vines can be produced when the proper parents are used in breeding. It is very probable that some self-fertile vines exist among the millions of wild plants, and thorough search should be made for such vines.

It is probable that originally the rotundifolia vines were self-fertile, but in the process of evolution this species has become practically dioecious. Very careful researches have suggested that this has happened in Vitis labrusca. Nearly all of the wild vines of this species appear to be self-sterile, but a number of seedlings have been found and produced that are self-fertile, and these have become the leading cultivated varieties of this species.

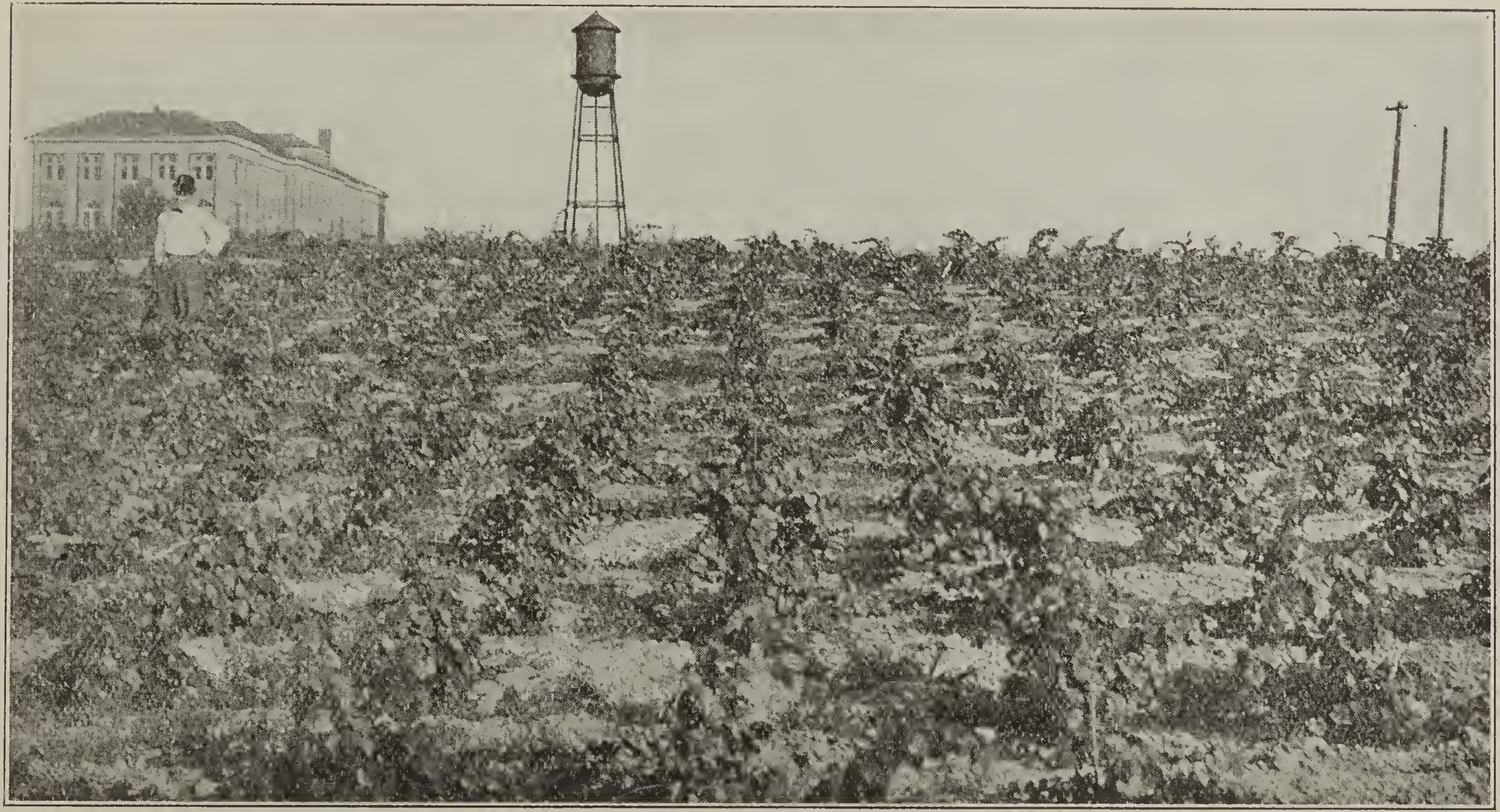

FIG. 8.—One-year-old seedlings in nursery. Vines tied to short stakes.

While it is evident that the rotundifolia grapes are more nearly dioecious than Vitis labrusca, the indications are that eventually we shall cultivate self-fertile rotundifolia varieties.

Transmission of Colors.

In our breeding work special attention has been given to the inheritance of colors. In fact a study of the transmission of colors has been the chief work of our breeding experiments. The reason why the early breeders gave up their breeding work was because nearly all of their seedlings from the Scuppernong were just the opposite in color from what they expected and wished. For several reasons already alluded to, it would be of little avail to attempt to improve at least the white varieties of this species, unless the white color could be transmitted to a large proportion of the seedlings. This the early experimenters were unable to do, for nearly all of their Scuppernong seedlings produced black fruits. From the following tables it will be seen that the white color can be transmitted to all the seedlings of the Scuppernong when the proper combinations are made in crossing.

In studying the tables that follow it should be borne in mind that color of vine and color of fruit is always correlated in this species. The varieties that produce white colored fruit are always light colored vines, and those that produce black or red fruit are always dark vines.

TABLE NO. 2.

Table Showing Colors of Vines and Fruit in the Hybrids.
Color of Scuppernong Hybrids.

Cross	Color of Plants	Color of Fruit
Scuppernong X Light Male No. 1	Light 1667 Dark none	White 339 Black none Red none
Scuppernong X Light Male No. 2	Light 20 Dark none	White 7 Black none Red none
Scuppernong X Light Male No. 3	Light 22 Dark none	No vines in bearing
Scuppernong X Dark Male No. 1	Light none Dark 644	White none Black 163 Red 141
Scuppernong X Dark Male No. 2	Light none Dark 49	White none Dark 1 Red none
Scuppernong X Dark Male No. 3	Light 67 Dark 118	No vines in bearing
Scuppernong X Dark Male No. 4	Light 24 Dark 19	No vines in bearing

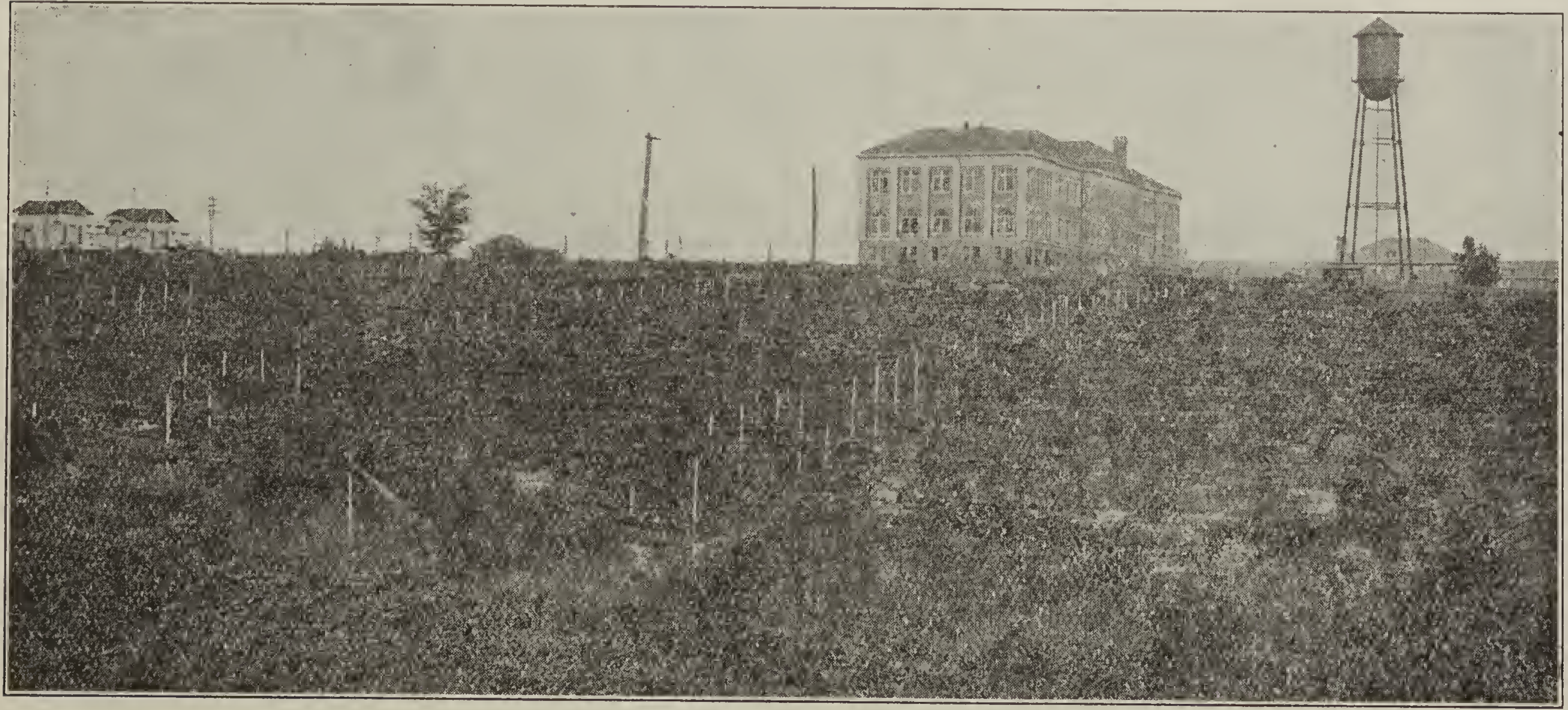

FIG. 9.—Grape vineyard. Seedings two seasons from seed trained to steel trellises.

It will be noted from this table that the numbers in the two columns do not correspond. This should be expected as about half of the vines included in the column under color of plants are male vines, and further, that not all of the pistillate vines have yet borne fruit.

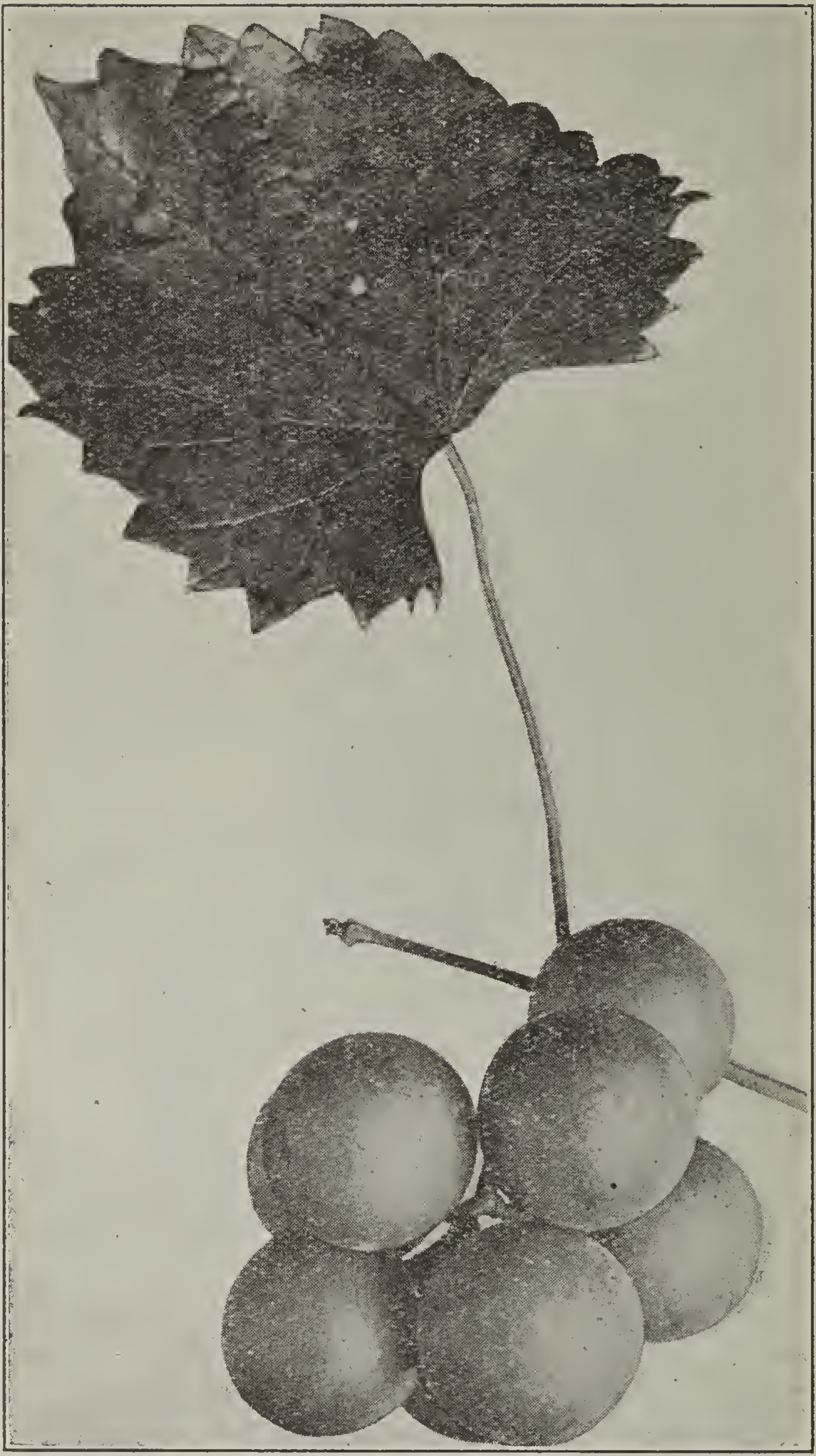

FIG. 10.—Cluster of white fruit of seedling of Scuppernong X Light Male Vine No. 2 (natural size).

The color of the Scuppernong varies from greenish to light cinnamon brown.

It will be seen that all the hybrid vines resulting from Scuppernong crossed with the light males used in our work are light in color; and that all of such hybrids which have borne have produced only white fruit. It is very probable that all of the other vines resulting from these crosses, but which have not yet fruited, will also produce white fruit.

While only three light males were used in these crosses, it is quite probable that whenever the Scuppernong is crossed with any light male rotundifolia vine the resulting seedlings will always produce white fruit. Our results show that the Scuppernong is pure for whiteness, and that it does not contain the dark color or the factor for the dark color in recessive form. It is also quite probable that every light male vine is pure for whiteness. Since both black and red colors are dominant over white in these grapes, all the hybrid male vines which carry the factor for black or for red, either or both, will always appear as dark. Hence the light male vines cannot possess the factor for black or for red even in the recessive form.

These results indicate that in breeding rotundifolia grapes white fruiting seedlings can be produced at will. By making the right combinations in crossing, each of the resulting female seedlings will produce white fruit. This fact will be of the greatest importance to grape breeders in the future. If the older grape breeders, who worked with the species, had known this fact it is very probable that we should now have many valuable white varieties of rotundifolia grapes, which might be far superior to the Scuppernong.

The seedlings that resulted from the Scuppernong crossed with pollen from dark male vines are very interesting, and the results obtained from such crosses will be of great value in future breeding work. From the table will be seen the fact that these crosses did not give as uniform results as did the hybrids of Scuppernong when crossed with light male vines. The dark male vines that were used in these crosses were of at least two types. Scuppernong when crossed with dark male vines No. 1 and No. 2 gave only dark seedlings, not a single light vine appeared in the hundreds of seedlings. The Scuppernong we know is homozygous for the white color; hence, some of the seedlings resulting from these crosses would also be light in color if the dark male vines contained the factors for the white color. Since all of the seedling vines that resulted from these crosses are dark in color, these dark male vines must contain factors for the dark colors only. The vines that resulted from Scuppernong crossed with dark male vine No. 1 are of two types, and about equally divided: one type produces red and the other black fruit. It is unfortunate that none of the vines from the hybrids that resulted from the Scuppernong crossed with dark male No. 2, have matured any fruits. The unripe berries, however, that were secured from one of these vines indicates that the color will be black fruit. Since none of the vines resulting from this cross are light in color it is certain that none of them will produce white fruit. (See Figs. 11 and 12.)

The resulting hybrids from Scuppernong crossed with dark male vines No. 3 and 4, give quite different results from those just discussed. In these crosses part of the hybrids are light in color, and part of them are dark. If a much larger number of hybrids had been produced in these crosses it is probable that the light and dark vines would be more equally divided. The dark male vines that were used in these crosses were not pure dark, but were heteroygous for both the light and

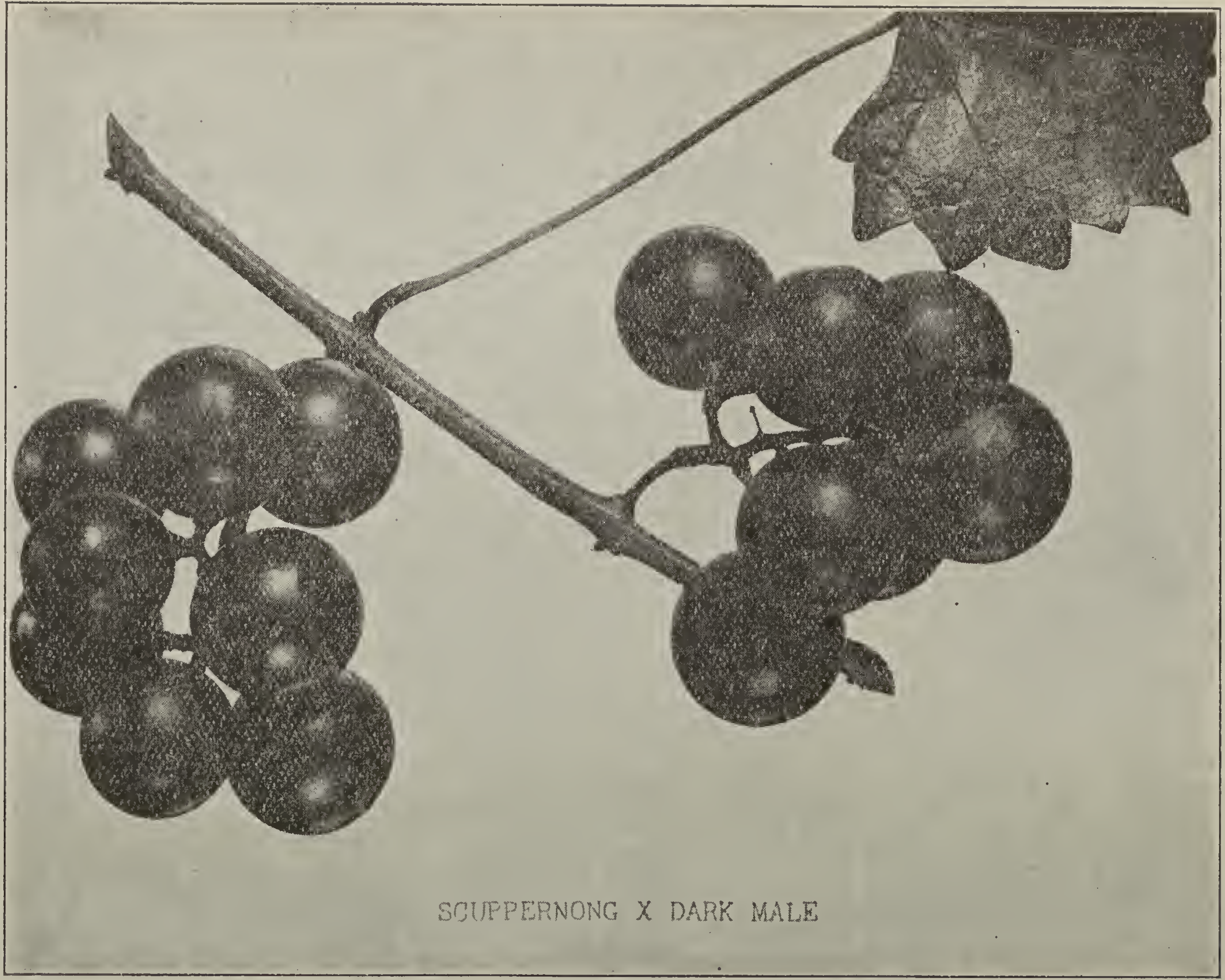
SCUPPERNONG X DARK MALE

FIG. 11.—Clusters of black fruit from seedlings of Scuppernong X Dark Male Vine No. 1.

the dark colors. The results indicate that these two male vines were already hybrids between dark and light vines; that the light color was present in the recessive form.

These hybrid seedlings reveal the fact that the male vines used in these crosses were of four types: pure light, pure black, hybrid carrying black and red, and hybrid carrying black and light. The first type can be readily distinguished from the last three, but we have not been able to distinguish between the last three from external or physical characters.

From these Scuppernong hybrids we can readily see that it is possible to produce vines with white fruit, black fruit, and red fruit by crossing with different male plants. It is possible to produce hybrids all of which will bear only white fruit, or hybrids all of which will bear only black or red fruits, or hybrids half of which will bear white fruit and the other half either red or black fruit.

The significance of this will be apparent to any one who has made a careful study of this species. One method of producing white varieties with larger fruit clusters than those of the Scuppernong will be by raising seedlings from seed of this variety which has been fertilized with pollen from male vines which have very large flower clusters. In this work the breeder will not be limited to light male vines with large flower clusters, but he will also be able to use some of the hybrid dark male vines with large flower clusters.

It is very apparent that color in all of these crosses is a Mendelian character.

TABLE No. 3.

Table Showing Color of James Hybrids.

Cross	Color of Plants	Color of Fruit
James X Light Male No. 1	Light 361	White 24
	Dark 330	Dark 28
James X Light Male No. 2	Light 49	No vines in bearing
	Dark 42	
James X Dark Male No. 2	Light none	White none
	Dark 62	Dark 1

The above table shows that the results that were obtained by crossing James with the light males No. 1 and 2 are similar. About one-half of these hybrids are dark and one-half are light colored vines. The light colored vines that have borne have produced only white fruit, and the dark vines have produced only black fruit. James, the female parent vine it will be remembered, bears fruit of a glossy black color. It is known from our work with the Scuppernong that the light male vines that were used in these crosses are homozygous for the light color. The hybrid vines secured therefore, prove that James is a natural hybrid vine, and that it carries the factors for the black and for the white colors.

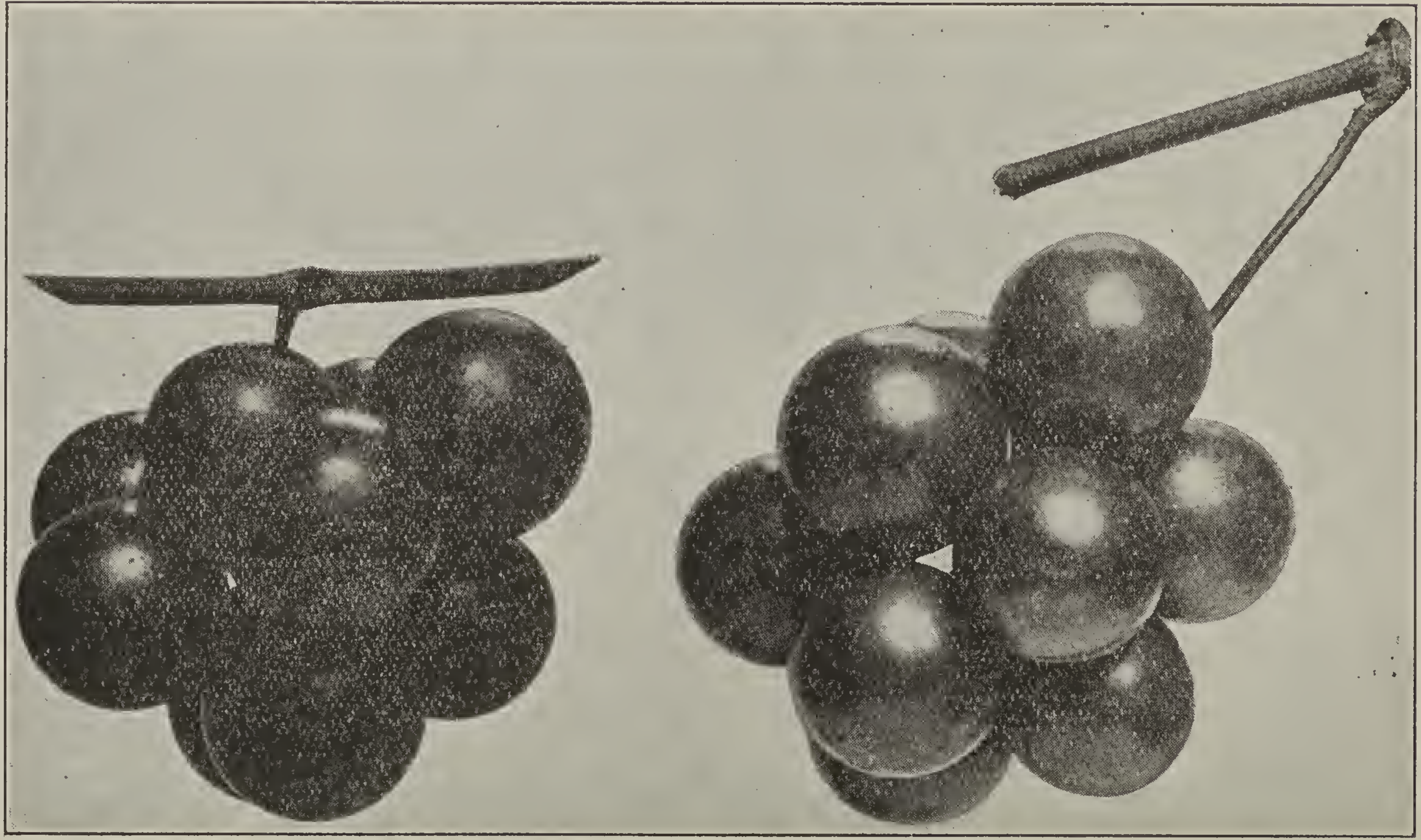

FIG. 12.—Clusters of fruit from light and dark colored seedling vines of James X Light Male Vine No. 1. Cluster on the right is white fruit from a light colored vine; cluster on the left is black fruit from a dark colored vine (natural size).

When James is crossed with Dark Male No. 2 the resulting hybrids are all dark in color. It has been shown that James is heterozygous for the white and for the black colors, therefore, the Dark Male vine No. 2 that was used in this cross must be homozygous, carrying only the dark color. The factor for the white color in James is latent and is also recessive to the factor for the dark color in this male vine.

The results that were obtained from James are of special importance, for it is regarded as a valuable variety for breeding purposes. The James is a vigorous grower, very prolific, and produces large berries which cling fairly well to the cluster, and it is one of the best shippers of the group. That this variety can be used as one of the parents in the production of either black, or white fruiting varieties, is evident from results obtained. Since this variety possesses some excellent characters that are not found in the Scuppernong it may become of considerable importance in the production of white varieties.

TABLE NO. 4.

Table Showing Color of Thomas Hybrids.

Cross	Color of Plants	Color of Fruit
Thomas X Light Male No. 1	Light none Dark 212	White none Black none Red 29
Thomas X Dark Male No. 2	Light none Dark 66	White none Dark 3

The light male vine that was used in this cross is known to be one that has the factor for the white color only. Therefore, these results show that Thomas is homozygous for red, and that red is dominant over white (See Fig. 13). Only 29 of the seedlings of this cross have fruited, and all of these have produced red fruit, the shades of which varied from wine color to that of almost black. These results are of especial value because the Thomas is the only red variety of this species that is now widely cultivated. The question of producing new red varieties of this species now becomes a very simple matter, and the need for such work is very apparent, when we consider that Thomas possesses some objectionable as well as some desirable characters.

It is to be regretted that none of the seedlings of Thomas crossed with a pure dark male vine have matured their fruits far enough to determine with any degree of accuracy whether they will be black or whether they will be red in color. From the scarcity of the red fruiting vines in Nature, also from the various shades of red that fairly lose themselves within the black, we assume that the black color is dominant over that of the red; and that therefore, all of these seedlings that are destined to bear will produce black fruit.

While no white fruiting seedlings have been produced from the Thomas crossed with a light male vine, we believe that such white seedlings can be produced in the second generation. These first generation hybrids possess the white character in recessive form. When such hybrids are again crossed with a pure light male it is probable that part of the resulting seedlings will be light. This method will make it possible to produce a white variety possessing some of the desirable characteristics of the Thomas.

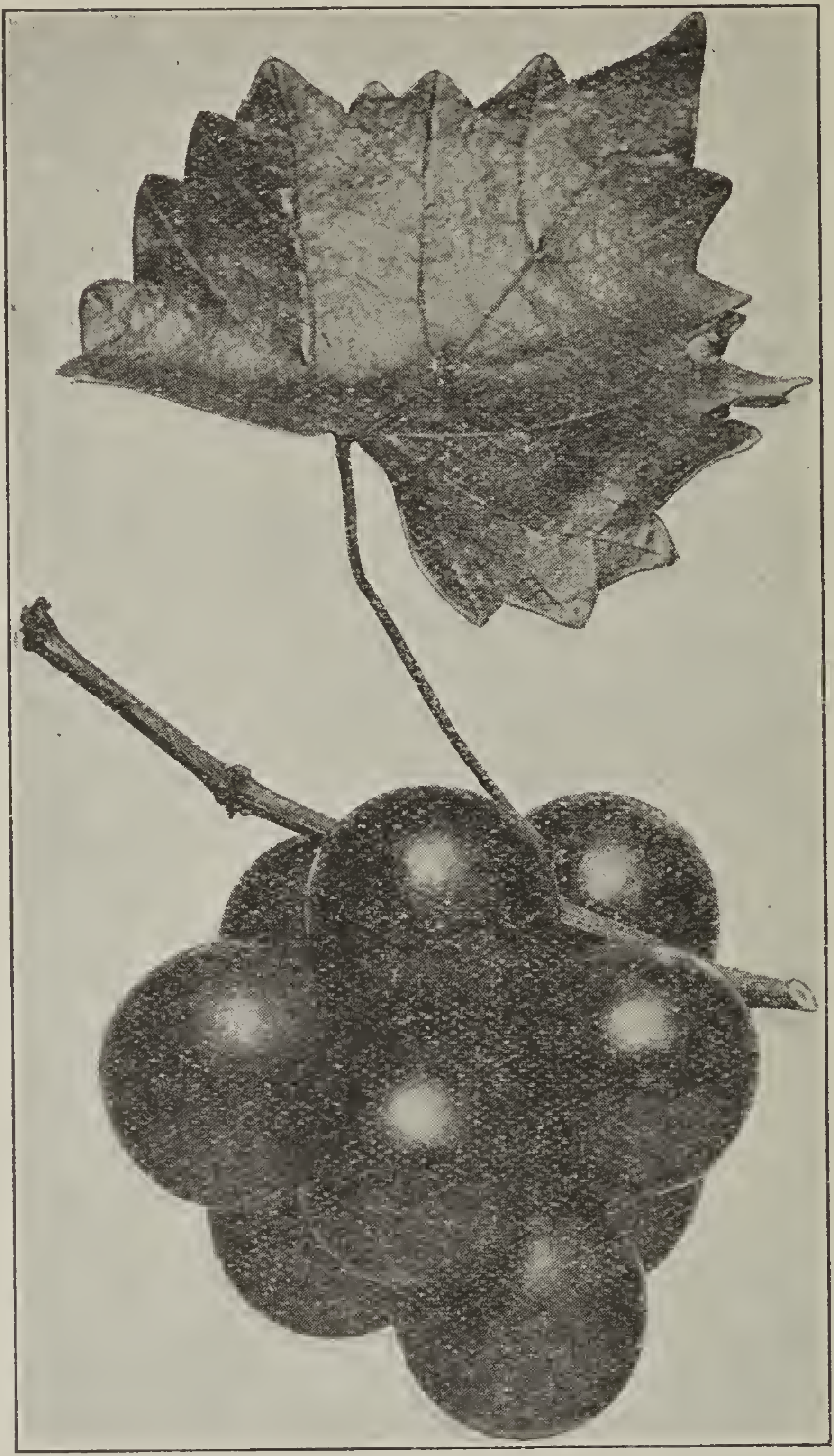

FIG. 13.—Cluster of red fruit of seedling of Thomas X Light Male Vine No. 1 (natural size).

TABLE NO. 5.

TABLE SHOWING COLOR OF FLOWERS HYBRIDS.

Cross	Color of Plants	Color of Fruit
Flowers X Light Male No. 1	Light none Dark 202	No vines in bearing

All the hybrids resulting from this cross are dark in color hence, all of them will produce only dark fruit, either black or red. The black color of the Flowers is completely dominant over the light color of the pure light male. From these results we must conclude that the Flowers is homozygous for the dark color, and does not contain the light color even in recessive form. To obtain white fruited seedlings from this variety it will be necessary to again cross these first generation seedlings with a pure light male, or to breed them inter-se. Since the Flowers possesses some valuable characters such as prolificacy, large clusters and excellent clinging qualities, it may prove of considerable value in breeding work. The undesirable characters of this variety, which must be eliminated, are its tough flesh, and very poor quality.

TABLE NO. 6.

Table Showing the Colors of Memory Hybrids.

Cross	Color of Plants	Color of Fruit
Memory X Light Male No. 1	Light 6 Dark 6	No vines in bearing
Memory X Light Male No. 1	Light 108 Dark 110	No vines in bearing

The fruit of Memory is black. When this variety is crossed with the pure light male vines, that were used in this work, practically one half of the resulting hybrids are light and one half are dark in color. Memory, therefore is heterozygous for the factors for both the light and the dark colors. From this it will be seen that Memory is a natural hybrid, that somewhere back in its ancestry a light colored vine and a dark colored vine were crossed, and as one of the hybrid offspring Memory retains the factors for both the light and the dark colors. These breeding results show that it is a very simple matter to obtain either light or dark colored seedlings from this variety. Since by crossing with a light colored male vine one half of the seedlings will be light, the possibilities of producing a valuable white fruiting variety is evident.

We have always regarded the Memory as one of the most valuable varieties of this group; and from the results obtained it is evident that this variety will prove of great value in breeding work. It has a characteristic oval shape, is prolific, clings fairly well to the cluster, and the fruit is sweet and of excellent quality.

TABLE NO. 7.

Table Showing the Color of the Latham Hybrids.

Cross	Color of Plants	Color of Fruit
Latham X Light Male Vine No. 1	Light 3 Dark 3	No vines in bearing
Latham X Light Male No. 1	Light 65 Dark 30	No vines in bearing

Latham is the only other red variety besides the Thomas, that was used in our breeding work. The results obtained in breeding this variety show that when it is crossed with a pure light male vine, about one half of the resulting hybrid seedling vines will be light and one half will be dark in color. This proves that Latham is a heterozygote possessing the dominant red color and the light color is the recessive form. Latham is a very fine variety and should be found in every collection where breeding work is attempted.

It is to be regretted that none of these hybrids have yet borne; but the most essential data so far as color is concerned, have been obtained.

TABLE NO. 8.

Table Showing the Color of the Mish Hybrid Seedlings.

Cross	Color of Plants	Color of Fruit
Mish X Light Male No. 1	Light none Dark 4	No vines in bearing
Mish X Dark Male No. 1	Light none Dark 1	No vines in bearing

While our work with this excellent variety is but very limited, the results, so far obtained, seem to indicate that Mish is a pure dark variety. When Mish is to be used in future breeding work and dark colors only are desired in the seedlings, they can be obtained by using for male parents preferably dark vines; however, for the first generation hybrids, any male vine will do. When white fruiting seedlings are desired, they can only be obtained in the second generation after Mish had been crossed with a light colored male vine.

TABL E NO. 9.

Table Showing the Color of the Smith Hybrid Seedlings.

Cross	Color of Plants	Color of Fruit
Smith X Light Male No. 1	Light 6 Dark 6	No vines in bearing

The Smith is a black variety closely resembling the Memory; and gives results similar to the Memory when crossed with a pure light male vine. Since our plants of this variety were small when the crossing was done, it was possible to obtain only a small number of hybrids. Just one half of these hybrids are light in color and one half are dark in color. This variety possesses fair keeping and shipping qualities, and as it gives both light and dark seedlings in the first generation it may prove of some value in breeding work. Judging simply from appearances, without knowing anything of the parentage of the Smith, we believe that it has no important characters for breeding purposes that are not already found in the Memory. This, however, can only be determined definitely by further work.

Conclusions Relative to Colors.

A careful study of the results obtained relative to colors of vines leads to the following conclusions:

First. That all the crosses between a light variety and a light male vine produce only light plants.

Second. That all the crosses between a pure dark variety and a pure dark male vine produce only dark vines.

Third. That all the crosses between a pure light variety and a pure dark male vine produce only dark plants.

Fourth. That all crosses between a pure dark variety and a pure light male vine produce only dark plants.

Fifth. That in all the crosses between a pure light variety and a dark male vine, which possesses the light color in the recessive form, practically one half of the resulting seedlings will be dark and one half will be light in color.

Sixth. That in all the crosses between a dark variety, which possesses the light color in the recessive form, and a pure dark male, the hybrids will all be dark in color.

A study of the results obtained relative to colors of fruits in the hybrids leads to the following conclusions.

First. All hybrids resulting from a pure light variety crossed with a pure light male vine produce only white fruits.

Second. All hybrids resulting from pure dark varieties crossed with pure dark male vines produce only dark fruits.

Third. All hybrids resulting from a pure light variety when crossed with a pure dark male vine, produce only dark fruits.

Fourth. All hybrids resulting from a pure red variety when crossed with a pure light male, produce only red or reddish fruits.

Fifth. Hybrids resulting from a dark variety, that has the white color recessive, when crossed with a pure light male vine, will be of two kinds and about equally divided: those that are light in vine characters will produce white fruits, and those that are dark in vine characters will produce either black or red fruit depending upon the inherent dark colors of the parent vines.

Sixth. Hybrids resulting from a pure light variety, when crossed with a dark male which is heterozygous for black and red, will be of two kinds and about equally divided: those that will produce black fruit and those that will produce red fruit.

Seventh. Hybrids resulting from a red variety, that is heterozygous for the red and the white colors, when crossed with a pure light male vine, will be of two kinds and about equally divided: those that possess the light vine character will produce white fruits, and those that possess the dark vine characters will produce red fruit.

Eighth. That color of the vine and of the fruit in rotundifolia grapes is a Mendelian character, and that they behave as such.

Ninth. That sap coloration in seedlings of rotundifolia grapes is dominant over the absence of sap color.

Tenth. That the rotundifolia grape vines, both male and female, are either pure white, pure black, pure red, heterozygous for black and white, for black and red, or for red and white.

Combinations Suggested for Breeding Work.

To those who wish to take up breeding work with this species and wish to give attention to color, we wish to suggest the following combinations:

For new white varieties:

Scuppernong	X Light Males.
James	X Light Males.
Memory	X Light Males.
Latham	X Light Males.
Smith	X Light Males.

Only about one-half of the fruiting seedlings resulting from each of the last four combinations suggested will produce white fruit.

For new black varieties:

Scuppernong	X Pure Dark Male.
James	X Pure Dark Male.
Flowers	X Pure Dark Male.
Memory	X Pure Dark Male.

For new red varieties:

Thomas X Light Male.
Scuppernong X Dark Males Heterozygous for red and black.
Latham, heterozygous for red and white, X Light Male.

SIZE OF THE FLOWER CLUSTERS OF THE HYBRIDS.

Attention has been called to the fact that the fruit clusters of these varieties are too small for present market requirements. One of the first and most important improvements to be made is an increase in size of the flower cluster and consequently the fruit cluster. That the flower cluster can be increased in size is shown by the data presented herewith. This data is confined to three varieties.

TABLE NO. 10

TABLE SHOWING SIZE OF FLOWER CLUSTERS OF HYBRIDS.

Parents	Size of Flower Clusters				
	Very Small	Small	Medium	Large	Very Large
Scuppernong X Male having small flower clusters	2	4	2	0	0
Scuppernong X Male having large flower clusters	252	165	74	3	0
Scuppernong X Male having very large flower clusters	43	84	157	15	7
James X Male having large flower clusters	32	25	7	0	0
Thomas X Male having large flower clusters	12	4	6	1	0

It will be noted that where the Scuppernong was crossed with a male vine having small flower clusters that none of the hybrids produced flower clusters above medium size. Where this same variety was crossed with a male having large sized flower clusters only three, or less than one per cent, of the hybrid vines produced large flower clusters. But where the Scuppernong was crossed with a male having very large flower clusters, fifteen, or nearly five per cent of the hybrids have large flower clusters, and seven or over two per cent have very large flower clusters. It will be seen that none of the hybrids produced very large flower clusters except those resulting from the male having very large flower clusters (See Figs. 14, 15, and 16).

In this classification we have designated flower clusters as follows: Those having from 1-9 flowers as "very small", 10-29 as "small", 30-59 as "medium", 60-89 as "large", and 90 or more as "very large."

SIZE OF FRUIT IN THE CLUSTERS.

That the size of the flower clusters determines in a measure the size of the fruit cluster will be seen from the following table:

TABLE NO. 11.

TABLE SHOWING SIZE OF FRUIT CLUSTERS IN THE HYBRIDS.

Parents	Size of Fruit Clusters				
	Very Small 1-3	Small 4-9	Medium 10-19	Large 20-30	Very Large 30+
Scuppernong X Male having small flower clusters	3	5	0	0	0
Scuppernong X Male with large flower clusters	221	94	24	0	0
Scuppernong X Male with large flower clusters	39	90	171	4	0
James X Male with large flower clusters	35	15	3	0	0
Thomas X Male with large flower clusters	17	11	1	0	0

This table corresponds fairly well with the previous one which gives the size of the flower clusters. Where the Scuppernong was crossed with a male having small flower clusters all of the hybrids produced either small or very small fruit clusters. When this variety is crossed with a male having large sized flower clusters seven per cent of the hybrids produced medium sized fruit clusters. When it is crossed with a male having very large flower clusters fifty-six per cent of the hybrids have medium sized clusters, and over one per cent have large fruit clusters. The results from the James and Thomas crossed with a male having large sized flower clusters are self explanatory.

These results show that the male vine is of considerable importance in determining the size of the fruit clusters of the hybrids. Therefore every effort should be made to find the male vines having the very largest flower clusters, where any breeding work is attempted.

Records in our possession show that all the vines which produce small flower clusters always produce very small fruit clusters. Also that the very largest fruit clusters are produced on vines which produce very large flower clusters. But the size of the fruit cluster does

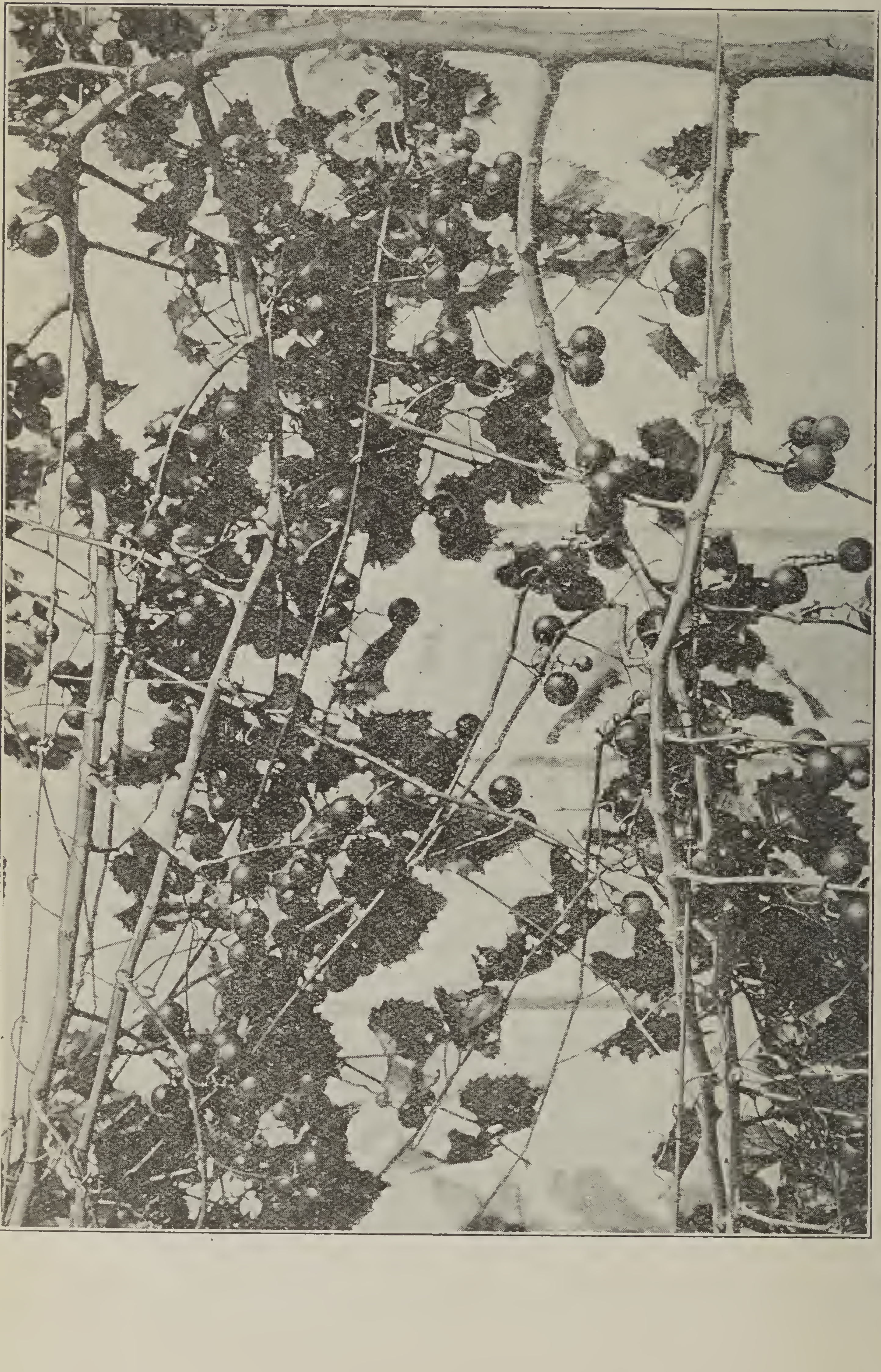

FIG. 14.—Purple fruited seedling of Scuppernong X Dark Male No. 1. A very small fruit clustered vine. This vine in 1913 bore very many flower clusters of large size, the largest of which by count contained seventy-three flower buds. The fruit clusters, however, are very small.

not increase proportionately with the size of the flower cluster. There appears to be a limit to the size of the fruit cluster which seems to be somewheres between twenty-five and thirty berries. Among our hybrid vines many clusters were observed that had more than seventy flowers, but no fruit cluster could be found which had more than twenty-three berries, and this where there was an abundance of pollen from male vines. The largest fruit cluster ever found by the writers on the best Scuppernong vines had twenty-seven berries.

We have found that the hybrids which produce the largest clusters also produced the greatest number of flower clusters per vine. The male vine used in the production of these hybrids produced very large clusters and these in great profusion.

Size of the Berries of the Hybrid Seedling Vines.

That the size of the berries can be modified by breeding is also shown by our work. Since we do not know the parentage of the male vines used in this work, it is impossible to say just what influence the male vines have had in determining the size of the berries of these hybrids. It is evident, however, that the size of the berries may be increasd or decreased by breeding. We do not find any correlation between the size of the fruit cluster and the size of the berries. The berries on some of the largest clusters are just as large as those on some of the smallest clusters.

TABLE NO. 12.

Table Showing the Relative Sizes of the Berries.

Parents	Small	Medium	Large	Very Large
Scuppernong X Male vine with small flower clusters	0	4	3	0
Scuppernong X Male vine with large flower clusters	1	173	162	0
Scuppernong X Male vine with large flower clusters	5	128	167	3
James X Male vine with large flower clusters	0	10	40	2
Thomas X Male vine with large flower clusters	1	24	3	0

The above tabulated results seem to indicate quite clearly, that the mother parent vines apparently control to some extent the size of the berries of their progeny. Of course we must keep in mind the fact that we know very little of the parentage of the different male viles that were used in these experiments. However, since Light Male Vine No. 2 was used with three varieties, each of which bears fruit of a different size, we note some very interesting results: The seedlings of Thomas, crossed with this male vine, produced fruits mostly of medium size. The seedlings of the Scuppernong, crossed with this male vine, produced fruits of different sizes, ranging all the way from medium to large. The seedlings of James, crossed with this same male vine, produced mostly large and very large fruits.

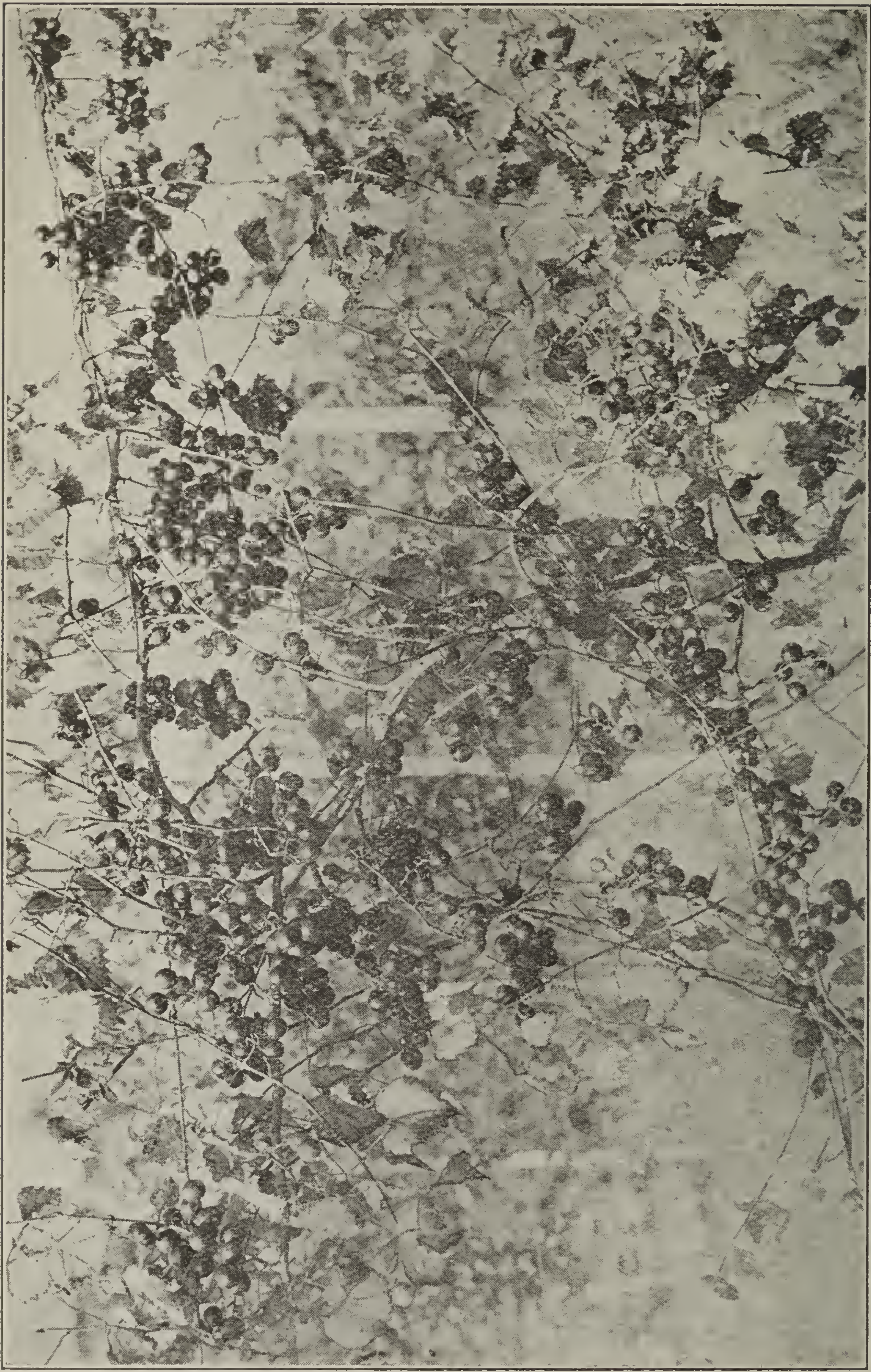

Fig. 15.—A black-fruited seedling of Scuppernong X Dark Male No. 1. A heavy bearing vine with average sized fruit clusters. This vine is three seasons from seed.

THICKNESS OF SKIN.

The following table shows that a very large percentage of the hybrids produce fruit with thick or with very thick skin. The Scuppernong hybrids include 392 with thick skin, and 117 with very thick skin; and only 66 with thinner skin than the Scuppernong. James has a very strong tendency to transmit a very thick skin to it's offspring. Out of a total of 52 fruiting vines, with James as one of the parents, only two were observed that produced fruits with a thinner skin than its parent. The results of the Thomas seedlings are surprising, for every one of it s hybrids has a thicker skin than the parent.

TABLE NO. 13

TABLE SHOWING THE THICKNESS OF THE SKINS OF HYBRIDS FROM THOMAS.

Parents	Very Thin	Thin	Medium	Thick	Very Thick
Scuppernong X Light Male No. 1	0	0	0	5	2
Scuppernong X Light Male No. 2	0	0	15	187	65
Scuppernong X Dark Male No. 1	0	9	42	200	50
James X Light Male No. 1	0	0	2	29	21
Thomas X Light Male No. 1	0	0	4	18	7

Character of the Pulp of the Hybrid Seedlings.

The pulp or flesh of all of our cultivated varieties of rotundifolia grapes is greatly in need of improvement. The pulp of most of the varieties is soft and stringy, while of others it is rather tough. For shipping purposes we need varieties with firm, meaty, but tender pulp. That such varieties can be produced is indicated by the following table:

TABLE NO. 14.

TABLE SHOWING THE CHARACTER OF THE PULP OF THE HYBRID SEEDLINGS.

Parents	Very Soft	Soft	Firm	Stringy
Scuppernong X Light Male No. 1	0	7	0	----------
Scuppernong X Light Male No. 2	3	141	14	----------
Scuppernong X Dark Male No. 1	9	284	9	41
James X Light Male No. 1	1	44	5	----------
Thomas X Light Male No. 1	0	24	5	----------

The vast majority of the hybrids are similar to the parents in the character of pulp. With the exception of the hybrids of Scuppernong, crossed with Light Male No. 1, which includes only a small number of vines, all of the crosses produced some vines that produce rather firm flesh.

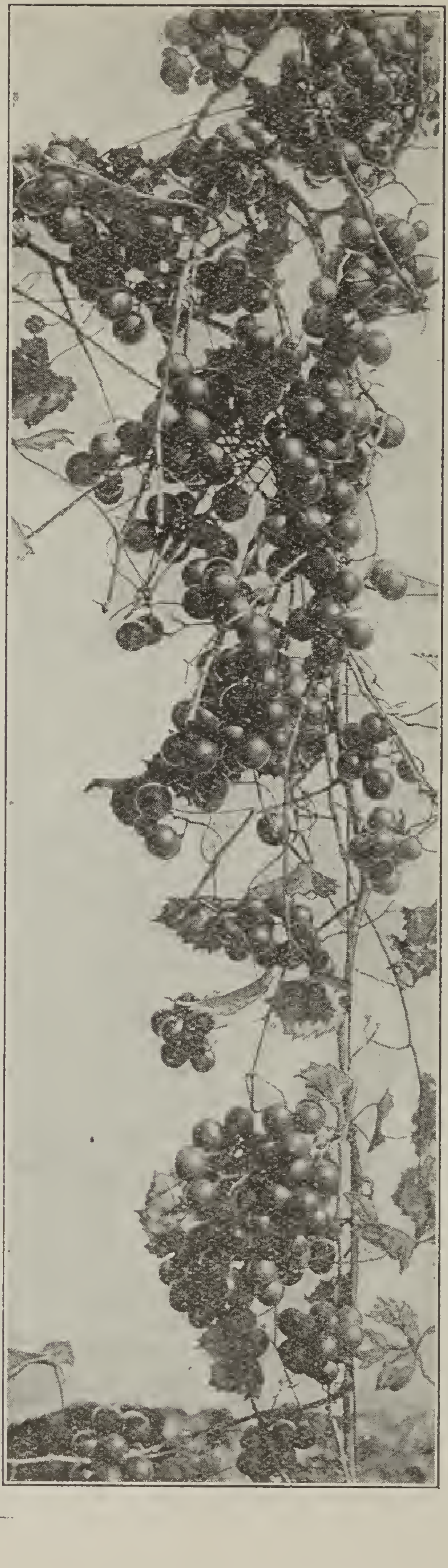

Fig. 16.—Red fruited seedling of Scuppernong X Dark Male Vine No. 1 (large fruit clusters).

Size of Seeds in the First Generation Hybrids.

Among the best varieties of rotundifolia grapes we have represented, roughly, four sizes of seeds; the small represented by those of Thomas, the medium by those of Mish, the large by those of Scuppernong, and the very large by those of James (See Fig. 17).

By crossing these varieties with any male vine, and by observing the resulting seedlings as to size of seed, one can pretty well estimate the influence of this male vine on the size of seed of these varieties.

TABLE NO. 15.

SIZE OF SEEDS OF THE FIRST GENERATION OF HYBRID VINES.

Parents	Small	Medium	Large	Very Large
Thomas X Light Male No. 2	1	21	7	0
Scuppernong X Light Male No. 2	0	50	206	9
James X Light Male No. 2	0	1	26	24

From this table it will be observed that the mother plant seems to exert, on the size of the seeds of its progeny, an influence equal to that of the male vine. In this case, Thomas seedlings produced seeds of a medium size, which leads us to infer that the male vine carried a corresponding factor for large seeds. Scuppernong seedlings, with this same male vine, produced mostly large seeds, with some variations on either side. The seedlings of James produced mostly large and very large seeds.

The results indicate quite clearly that in order to reduce the size of the seeds in rotundifolia grapes, we must utilize vines that carry the factor for smaller seeds.

Flavor and Quality in Rotundifolia Grape Seedlings.

Knowing but very little of the parent vines of our cultivated varieties of rotundifolia grapes, and of the several male vines that have been used in our breeding work, we are not prepared to make unqualified statements as to the mode of transmission of characters, such as flavors and qualities. The fact that the rotundifolia grapes are self-sterile, makes this doubly difficult, for we know nothing of the good or the bad qualities of male vines, even though these be the immediate descendants from good quality mother vines.

Careful breeding in the past for quality has not been done with the rotundifolia grapes. Although the Scuppernong grape has been cultivated for the last century and a half, but very few seedlings of merit from this variety are reported, and with none of these do we have any authentic data of the parent male vines. These facts are readily comprehended when we reflect that only recently (Bul. 209, N. C. Agr. Exp. Station) the truth of the self-sterility of the Scuppernong and other rotundifolia grapes has been firmly established.

Very nearly all of our cultivated varieties of rotundifolia grapes, are vines that have been found growing wild in and about our woods and swamps, hence our very meagre knowledge of their pedigree. It is of the utmost importance to know the parentage of a series of vines, at least several generations back, before principles of laws, governing the transmission of such characters as those heretofore mentioned, can be laid down with any degree of safety.

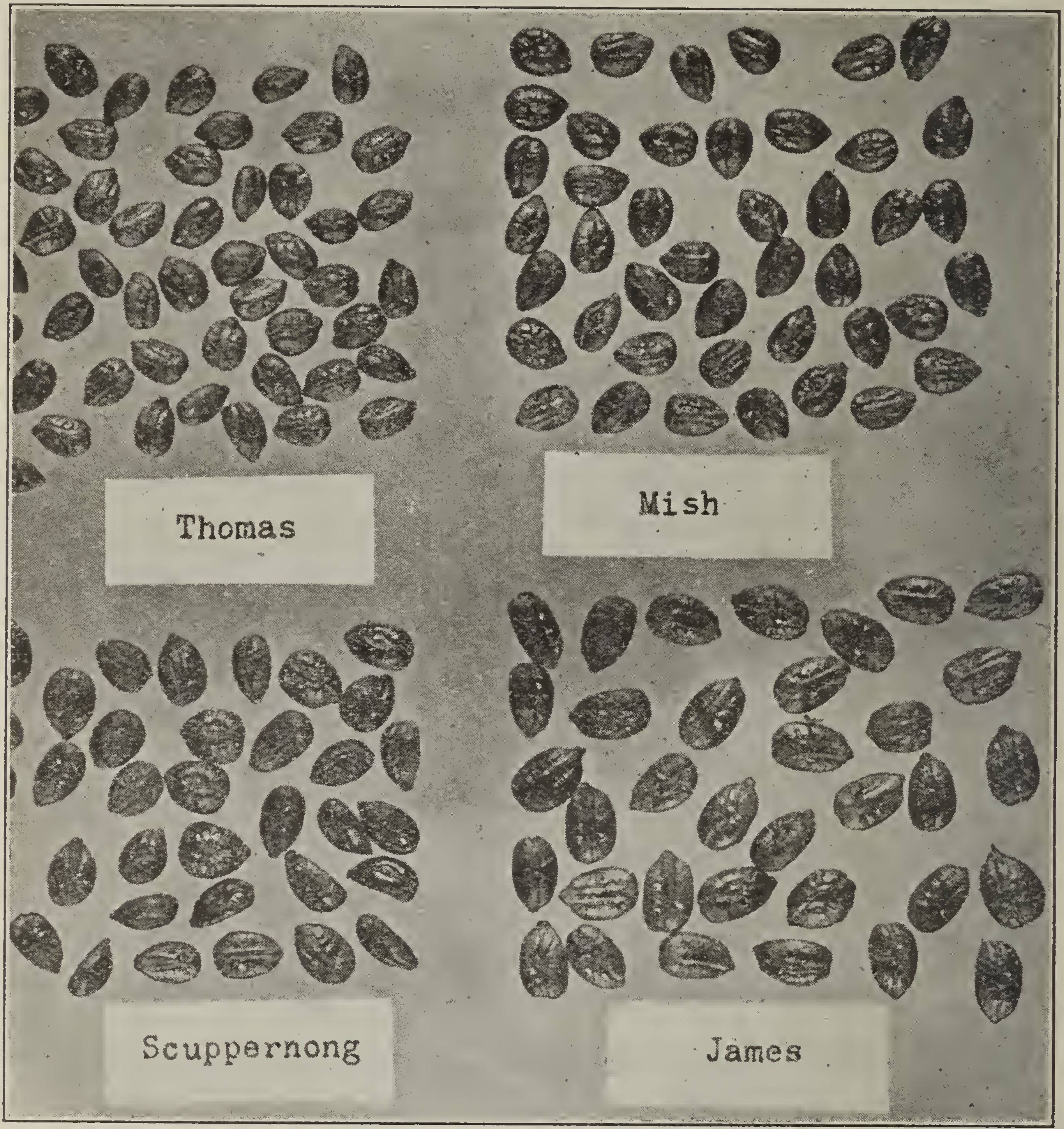

FIG. 17.—Vitis rotundifolia seeds. Thomas, Mish, Scuppernong, and James (natural size).

Flavors are of variable characters, difficult to describe, because of their very complexity. Just a slight variation in one or the other of the many characters that go to make up this quality, will lend an entirely new color to a given combination.

Probably a better way to study the flavors of fruits is to analyze them into their respective component parts, and to study these separately as well as in combination with each other. Take for example the sugar content of grapes; it is a fact quite patent to the most casual observer, that different varieties of grapes differ materially in the quantities of sugar that they develop. Some develop a comparatively high degree of glucose, while others mature with a much less quantity. (Found. Am. Grape Culture, by T. V. Munson, pp. 122-125.) (U. S. Dept. Agr., Bul. 273, Bureau Plant Ind., pp. 39-40).

TABLE NO. 16.

Acidity in Seedling Rotundifolia Grapes.

Parent Vines	Sweet	Sub-acid	Acid	Very Acid
Scuppernong X Light Male No. 1	0	7	0	0
Scuppernong X Light Male Vine No. 2	2	188	62	3
Scuppernong X Dark Male No. 1	6	213	81	3
James X Light Male No. 1	0	39	10	0
Thomas X Light Male No. 1	0	20	8	1

It will be noticed that, in the table, the majority of the seedling vines fall in the second column under the sub-acid heading. Since the mother vines produce fruits of a sub-acid character, and absolutely nothing of this nature is known about the male vines, it seems plausible that by line breeding and selection, the percentage of offspring that produce acid fruits might be decreased considerably. It will furthermore be noticed that not only acid and sub-acid fruits have occurred, but some few vines that produce sweet berries have been discovered. This great variation in sweetness and in acidity of fruits allows the breeder ample room for choice of vines.

Taste alone, however, is but a poor guide for guaging the accurate saccharine content of fruits; because other components, as for instance acidity in varying degrees, materially affects and modifies sweetness, according to the sense of taste. Grapes low in sugar, and relatively lower in acid, might be pronounced sweet, while others higher in sugar, but with relatively more acid, would be termed not so sweet. (Found. Am. Grape Cult., by T. V. Munson, pp. 122-123.) Hence grapes that are to be used for specific purposes, with a higher or a lower degree of sugar or of acid, can be developed by selecting with the aid of scientific instruments, mother plants that record the desirable quantity of sugar and of acid; and by proper mating we may find in the first, second, or third generation, vines that measure up to our ideal. Although the actual amounts of sugar and of tartaric acid in grapes can be accurately measured, the agreeableness of any combination can only be guaged by means of the taste.

When we attempt to study the flavors in grapes we meet with another factor, which materially affects their agreeableness or eating quality; the aroma. This aroma is not lacking in the rotundifolia species, for early descriptions of the newly discovered continent contain glowing accounts of the strong odors of the vine. The articles undoubtedly refer to this group, because no other one species of grape abounds more plentifully along our Southern coasts.

While rotundifolia grapes generally are described as having a strong musky odor, many varieties exhibit aromas quite distinct and unique. The dark fruiting seedlings as a rule seem to vary much more in the intensity of aroma, while the light fruiting forms in this respect are less variable.

If, without experimenting, we could pick out male vines that possess inherent qualities of only good aromas, we could so mate the vines as to secure a high per cent. of excellent flavored seedlings; but, until we know the pedigree of these vines we will have to resort to selection of the bearing forms, as mother plants, and take our chances on the inherent qualities of the male vines.

Occasionally seedling grape vines are found that exhibit but a very little of the wild flavor, and among these we should look for the more delicately flavored fruits. Among these we find aromas both good and bad, mild and strong, and in varying degrees of intensity. Of course the number of these better quality seedlings depends entirely upon the inherent qualities of the parent vines. The results that are given in this publication refer to offspring of only such varieties as Scuppernong, Thomas, James, and of male vines that were selected only for color and size of cluster.

Two cases of very repugnant aromas have occurred among our seedlings from the Scuppernong, crossed with a dark colored male vine. Both of these partook very strongly of the odor of phenol. Needless to say that such odors in fruits are prohibitive and kill a variety without mercy, no matter how many other good qualities it may possess.

This variability, however, in sweetness, acidity, and aroma is the very keystone for quality to the grape breeder, because such maze of characters, with its manifold combinations and blendings, presents the very best chance for the selection of choice combinations. It is among these that we should look for vines with the best combination of characters. If some are found that seem promising, they should be marked for propagation, and be further tested before they are recommended for extensive planting.

TABLE NO. 17.

TABLE OF COMPARATIVE QUALITY IN SEEDLING ROTUNDIFOLIA GRAPES.

Parents	Very Poor	Poor	Fair	Good	Very Good	Best
Scuppernong X Light Male No. 1	0	0	1	3	3	0
Scuppernong X Light Male No. 2	2	27	130	84	10	1
Scuppernong X Dark Male No. 1	1	43	160	79	12	7
James X Light Male No. 1	0	8	27	13	0	0
Thomas X Light Male No. 1	0	3	16	7	1	0

The variability of the rotundifolia species is shown to some extent in the above tabulated results. The data presented is only tentative, however, for it has been taken from vines that were only three years old from the seed, and the fruits were tested during the season only. Nevertheless it shows the variability that may be expected in a group of seedlings that are the offspring of carefully selected mother vines.

While such varieties as Scuppernong, James, and Thomas are of good to excellent quality, it will be observed that their offspring group themselves principally in the column of *fair* quality. This undoubtedly is the result of the unknown parentage of the mother vines, and more specifically of the unknown qualities of the parent male vines. For although these produce no fruits and therefore cannot exhibit their inherent qualities, they are able to transmit any of the qualities that either of their parents possessed.

It will furthermore be observed, that out of a total of 638 bearing vines, only eight of exceptional quality were secured, or a ratio of about one to eighty. When we are able to select both parent vines that possess exceptionally good qualities, we will be able to increase this ratio considerably; for by proper selection we can intensify these good qualities.

Clinging Quality of the Berries.

A detailed study has been made of the clinging quality of the hybrids that were produced from Scuppernong, James, and Thomas. We were able to make only two classes: Those that ranked as very poor, and those that ranked as poor.

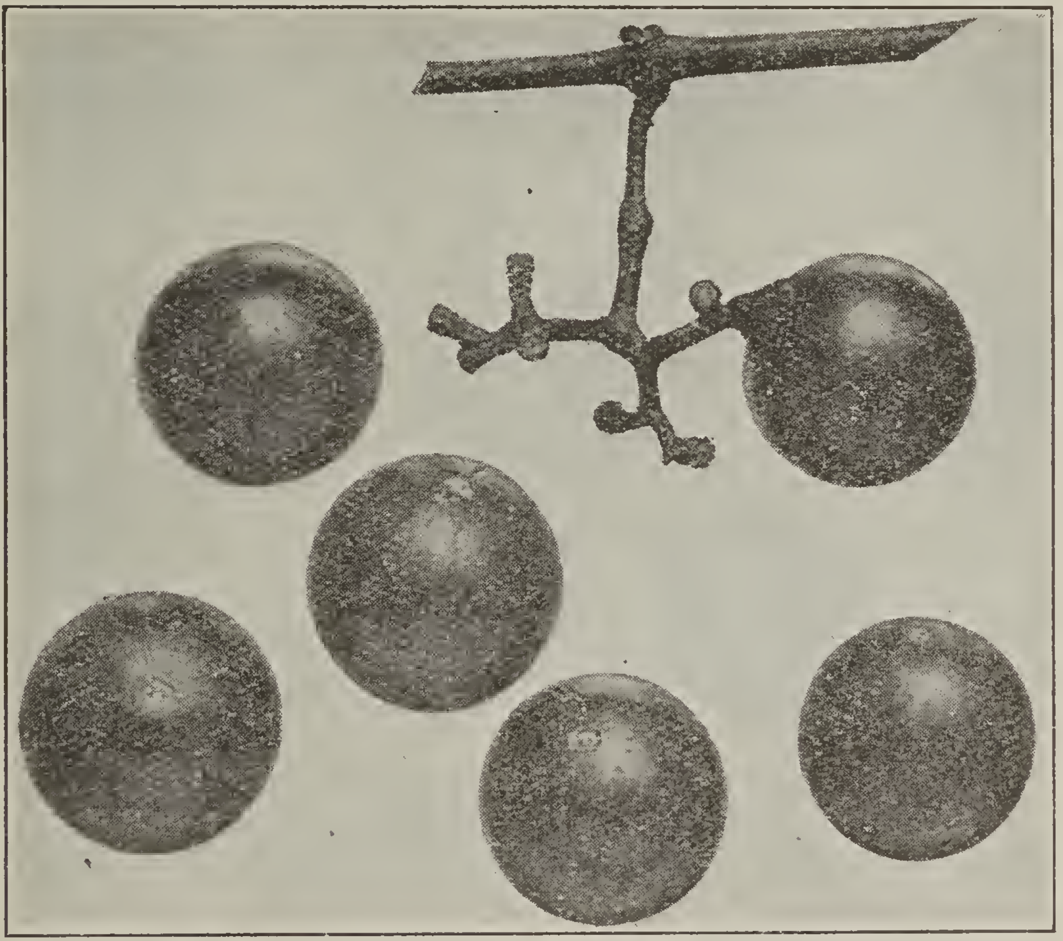

FIG. 18.—Shattered cluster of Scuppernong (natural size).

Those fruits that ranked as very poor dropped when ripe at the very touch of the hand, while those that were classed as poor were slightly more tenacious, clinging somewhat better than the Scuppernong (See Fig. 18). It is true that in this latter class bunches of grapes were frequently found that possessed a very tenacious clinging quality, but these bunches were the exception rather than the rule. By far the majority of the berries in this class revealed this clinging quality only in a very limited degree. Of the total number of fruit bearing vines, 415 were classed as very poor and 317 as poor.

It is hoped that better clinging quality will be obtained in the hybrids of the Flowers vine. These will be studied with exceptional interest in this respect, for the fruit of this variety clings much better than that of the other varieties (See Fig. 19).

Promising New Seedlings.

One of the most delightful events that a plant breeder looks forward to with a great deal of anticipated pleasure, is the appearance of promising new seedlings. Whenever a lot of seeds are planted there will be more or less variation found among the resulting plants. The extent and the quality of this variation, depends in a large measure on the selection of the parent plants. Accordingly in our breeding work we have selected as far as possible the best material that is offered in the rotundifolia species.

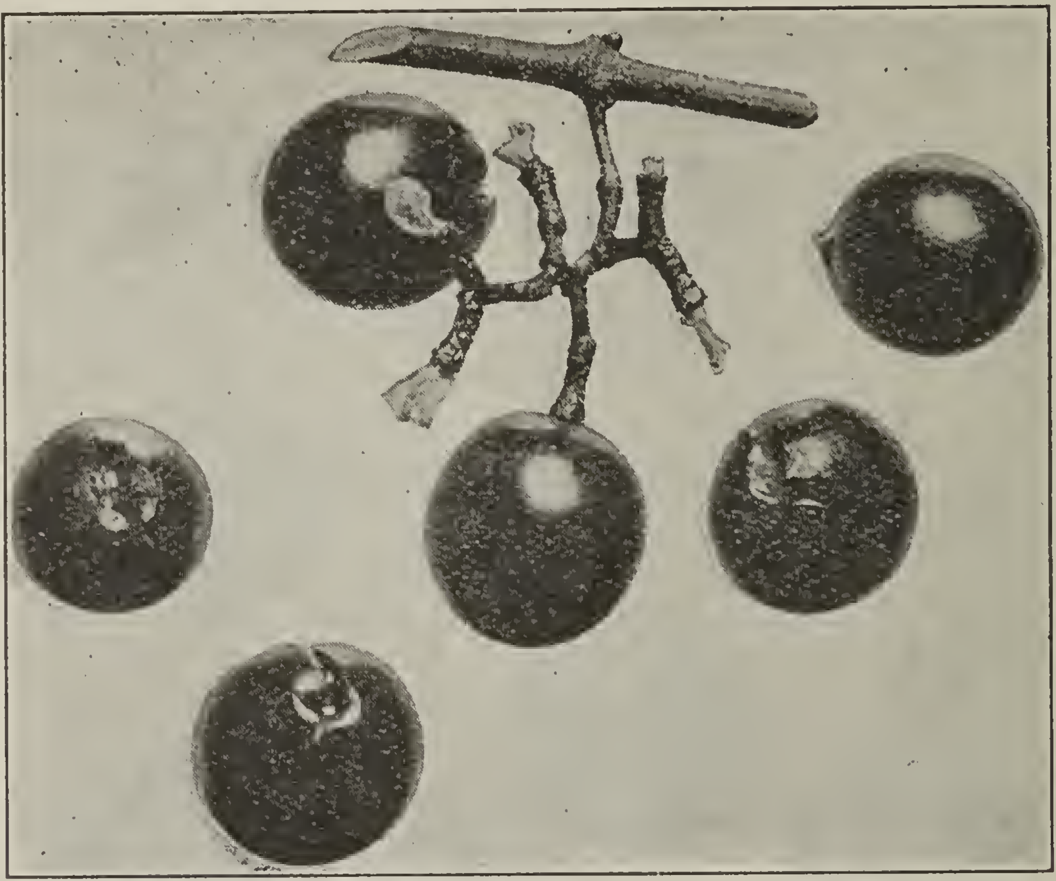

Fig. 19.—Cluster of variety Flowers, showing extreme of clinging quality (natural size).

It is to be regretted that one cannot foretell, or choose male vines, that possess inherent factors for good quality of the fruit. If this were possible we might, by making the proper combinations, secure in a lot of seedlings a much increased number of good quality vines. However, since this forecast is almost impossible, we have chosen the best quality mother vines, and have used for male parents only those that possess the greatest number of visably good vine characters. Among our 729 vines that fruited in 1913, several were noted that exhibited characters of especial merit. Some of these are of interest only to the plant breeder, while others will appeal to the consumer of the grape.

The following seedlings possess characters of interest mainly to the plant breeder:

Seedling No. 1 (James X Light Male, No. 1), F-13.

This seedling grape will be of interest only because of its color. All of the other light-colored offspring from James gave us fruits in color like that of the Scuppernong, but this one produces, instead of the cinnamon color, a pearly-green berry, semi-transluscent. Thus it will be seen that by proper breeding we can widen our range of colors in the fruits of the rotundifolia species.

Seedling No. 2 (Scuppernong X Dark Male, No. 1), P-48.

The character that recommends this seedling as a promising vine is its tendency to produce uniformly large fruit clusters. The berries are very large in size and violet-red in color.

The following seedlings are of interest because of their excellent fruit qualities:

Seedling No. 3 (Scuppernong X Dark Male, No. 1), U-23.

Fruit: Medium to large, black with a bluish bloom. Skin: Medium thick. Pulp: Soft and very juicy. Flavor: Mildly sub-acid and aromatic. Quality: Very good to best.

Seedling No. 4 (Scuppernong X Dark Male, No. 1), V-38.

Fruit: Medium to large; reddish-purple in color. Skin: Medium thick. Pulp: Soft and juicy. Flavor: Mildly sub-acid. Quality: Very good to best.

Seedling No. 5 (Scuppernong X Dark Male, No. 1), V-52.

Fruit: Small to medium; almost black in color. Skin: Thick. Pulp: Soft. Flavor: Mildly sub-acid and aromatic. Quality: Very good to best.

Seedling No. 6 (Scuppernong X Dark Male, No. 1), O-23.

Fruit: Large and black. Skin: Thick. Pulp: Very juicy, soft, and somewhat stringy. Flavor: Mildly sub-acid, and aromatic. Quality: Best.

Seedling No. 7 (Scuppernong X Dark Male, No. 1) W-18.

Fruit: Medium in size and almost wine-colored. Skin: Medium thick. Pulp: Soft. Flavor: Sweet to sub-acid, and aromatic. Quality: Very good to best.

Seedling No. 8 (Scuppernong X Dark Male, No. 1), W-38.

Fruit: Large, and of a beautiful violet-red color. Skin: Medium thick. Pulp: Very soft and juicy. Flavor: Very mildly sub-acid. Quality: Very good to best.

Seedling No. 9 (Scuppernong X Light Male, No. 2), Z-27.

Fruit: Large, and cinnamon in color. Skin: Thick to very thick. Pulp: Soft and somewhat stringy. Flavor: sub-acid. Quality: Very good to best.

Of course we realize the fact that young plants, as a rule, tend to produce better fruit than those that are older. But although these vines are only three years from seed, their qualities thus far observed recommend them for at least further observation, and entitle them to a trial.

HYBRIDIZATION WITH OTHER SPECIES OF GRAPES.

While excellent results may be obtained from careful breeding work within this species, it is possible that the greatest improvement will come from the crossing of this with other species of grapes. It may be necessary to hybridize it with other species to obtain uniformity of ripening, large clusters, and better clinging propensities.

We have done a limited amount of work in attempting to cross the Scuppernong with other species, with the following results:

Work Done in 1911.

Scuppernong flowers were treated with pollen from Vitis æstivalis. In this work five large canes, with many flower clusters, were covered with bags; and as the blossoms opened from time to time they were carefully hand pollinated. No fruits developed from these blossoms, hence no seeds were obtained.

In similar manner, Scuppernong flowers that were treated with pollen from Niagara (*V. labrusca*) produced no fruits.

Scuppernong flowers treated with pollen from male plants of *V. cinerea* produced no fruits.

Scuppernong flowers treated with pollen from Herbemont (*V. aestivalis bourquiniana*) produced one berry with four seeds. From these four seeds two plants were secured, but one of which is alive.

Work Done in 1912.

Five bunches of the Scuppernong were bagged, and the flowers were treated with pollen from *V. aestivalis.*

Five bunches of the Scuppernong were bagged, and the flowers were treated with pollen from Herbemont.

Five bunches of Scuppernong were bagged and the flowers were treated with pollen from Winchell (*V. labrusca*).

Results of this work—None of these combinations produced any fruits.

These results seem to indicate that such combinations are not very congenial, and if successful at all, proceed only with considerable difficulty.

SUMMARY.

Our breeding work with the rotundifolia grapes has led to the following conclusions:

1. That the sexes in seedlings of the rotundifolia grapes theoretically, are equally divided.
2. That colors in rotundifolia grapes behave as Mendelian characters; and that by making the proper combinations, seedlings of either white, red, or black colors can be produced at will.
3. That the Scuppernong, and all other white fruit-bearing vines, together with all light-colored male vines, are pure for the white color; and that they do not carry the dark color as a recessive factor.
4. That the Flowers, Mish, and Thomas are pure for dark colors, and do not carry the white color as a recessive factor.
5. That James, Memory, and Smith are natural hybrid vines; that they are heterozygous for the black and the white colors.
6. That Latham is a natural hybrid vine, heterozygous for the red and the white colors.
7. That many of the dark colored vines, both male and female, growing wild, are heterozygous for the colors black and white, black and red, or red and white.
8. That the white color is recessive to all dark colors.
9. That dark, red or black, colors are dominant over the white color.
10. That black is dominant over red.
11. That rotundifolia grape vines may be either pure white, pure black, pure red, heterozygous for black and white, black and red, or red and white.
12. That the light and dark colors of the vines are correlated with similar colors in the fruits of those respective vines.
13. That the average size of the fruit cluster can be enlarged by the judicious selection of very large-sized flower-clustered male vines.
14. That the actual size of the flower cluster, under good conditions for cross-pollination, does not determine the actual size of the resulting fruit cluster.
15. That self-sterility alone is not altogether responsible for the small-sized fruit clusters.
16. That the seedlings of rotundifolia grape vines vary considerably in size of berry, flavors and qualities, thickness of skin, character of pulp, and size of seed. That by proper combination of parent vines, desirable seedlings can be produced.
17. That the Scuppernong grape does not readily hybridize with *V. aestivalis, V. cinerea,* Herbemont, Winchell, and Niagara.

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AGRICULTURAL EXPERIMENT STATION

CONDUCTED JOINTLY BY THE

STATE DEPARTMENT OF AGRICULTURE

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COLLEGE OF AGRICULTURE AND MECHANIC ARTS

RALEIGH AND WEST RALEIGH

SELF-STERILITY IN DEWBERRIES AND BLACKBERRIES

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SELF-STERILITY IN DEWBERRIES AND BLACKBERRIES

BY L. R. DETJEN.

INTRODUCTION

The phenomenon of sterility may be caused by any one of a number of various factors. It may be caused by external agencies, such as excessive heat, cold, moisture, and a host of other such conditions; but, more frequently, it can be traced to a deep-seated internal origin.

Sterility is encountered almost everywhere; it ramifies all branches of the plant and animal kingdoms. As an agent in the hands of organic evolution, sterility plays a rôle of prime importance, while to the breeder of improved forms it not infrequently becomes a menace and a stumbling block to further progress.

Sterility is a factor which is confined not only to the spheres of organic improvement and to evolution in general, but also to that of the production of fruit crops. In the latter field it becomes a factor of the utmost importance. In the planning of the older fruit plantations the factors of sterility were not recognized, and hence the innumerable financial failures, which, by a little knowledge of the comparative fertility of varieties, might well have been averted. Examples of this faulty planning of fruit plantations are very numerous, and only a few concrete examples will suffice to evince the real significance of the factors of sterility. Bartlett pear trees when set in large solid blocks have generally proven unprofitable to the grower. V. R. Gardner in his "Pollination of the Sweet Cherry," Oregon Experiment Station Bulletin, No. 116, points out the fact that among the more recent plantings of the sweet cherries, the fruit growers in Oregon have unconsciously selected varieties such as Napoleon, Bing, Lambert, and others, which are not only self-sterile, but also intersterile, as recent investigations have proven. In such cases even the selection of a list of varieties may not always constitute a remedy, and such practice when not carefully done may be no better than the planting of a whole block of a single self-sterile variety.

The large vineyards of Rotundifolia grapes in North Carolina give evidence of a lack of a sufficient number of pollinizers. These vineyards were planted upon the supposition that the different varieties of Muscadine grapes were self-fertile; but even so, in many instances provision was made for the cross-pollination of the different varieties. Later investigations regarding the self-sterility of rotundifolia grapes (N. C. Bulletin, No. 209) produced evidence that all of the cultivated varieties of these grapes are self-sterile, and also inter-sterile, and that for successful fruit production the presence of male vines in large vineyards is absolutely essential.

Even the growers of small fruits are not immune from the harmful effects of sterility when certain varieties are planted in solid blocks. Fortunately for the commercial growers in the eastern States, the leading varieties of dewberries and blackberries are self-fertile and produce abundantly even when planted in large solid areas. However, there are many excellent varieties on the markets which are more or less influenced by the factor of sterility, and which, with judicious care in the selection of varieties with regard to pollination, can be made to yield profitable crops. In fact, there are a number of varieties which are likely to prove to be just as good as the chief commercial varieties of the present day, barring this one defect.

Object of the Experiment.—The prime object of the experiment under discussion was to investigate the question of sterility among varieties of dewberries and blackberries. This question resolves itself into the following three lines of investigation: first, to ascertain which varieties of dewberries and which varieties of blackberries are self-fertile and which are self-sterile; second, to discover, if possible, the cause or causes of this sterility; and, third, if possible, to suggest remedies.

STERILITY AMONG DEWBERRIES AND BLACKBERRIES.

Varieties Tested.—In order to provide sufficient material in the way of varieties to carry on this sterility test, the following varieties were secured and planted under ordinary field conditions:

Dewberries
Austin
Chestnut
Grandee
Limekiln
Lucretia
Manatee
Munroe
Rogers
Elijah, No. 2
Premo
San Jacinto
White

Hybrids
Cox
Ruth
Haupt
Rathbun
McDonald
Wilson
Sorsby
Spalding

Blackberries
Blowers
Dallas
Early Cluster
Early Harvest
Eldorado
Illinois
Kenoyer
King
Mersereau
Minnewaski
Snyder

Method of Procedure.—The method used to test these varieties for self-sterility may be stated as follows: whole flower-clusters, and oftentimes several of them, were inclosed in bags so as to exclude all foreign pollen. Some of these bags were ordinary half-pound paper sacks, while others were made of cloth. The latter were made of Pacific lawn, which is a light, gauzy, but very fine-meshed fabric, and which successfully keeps out all foreign pollen.

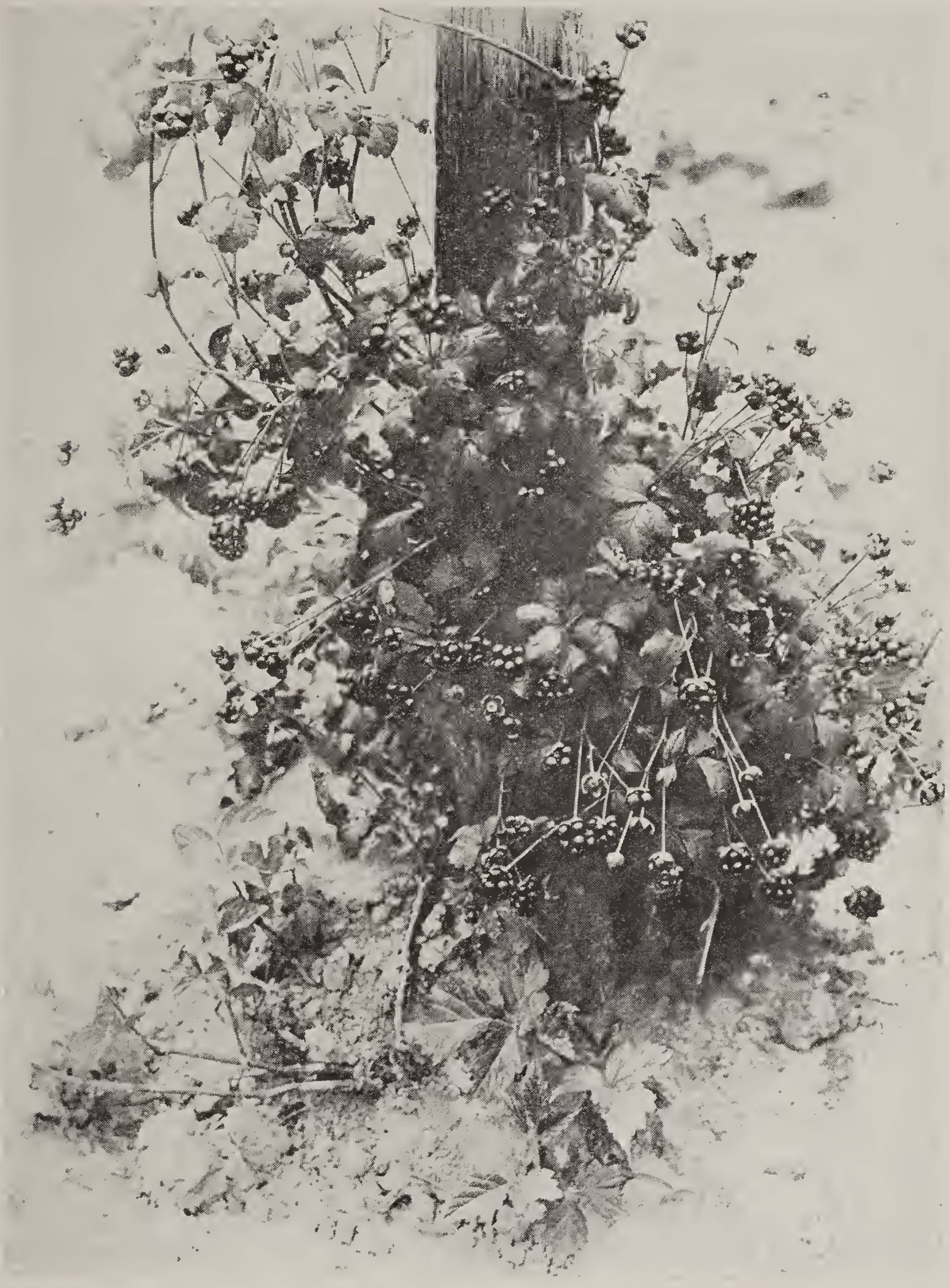

Fig. 1.—Premo, a self-sterile variety, produces a crop of nubbins when supplied with an insufficient amount of acceptable pollen.

The relative number of flowers inclosed in each bag depends entirely upon the species to which the respective varieties belong. Generally speaking, the flower clusters of *Rubus villosus* have relatively large numbers of flower buds, while those of *R. trivialis* usually possess from one to three.

By covering the flower clusters before any of the buds had opened or immediately after the careful removal of such as had opened, thus preventing all foreign pollen from gaining access to the flowers within, the potency of the pollen within the imprisoned flowers was tested. The flower clusters of each variety were covered during the forepart of their respective blooming periods, and to insure a length of time sufficient for fertilization to manifest itself the bags were not removed until it became evident to the most casual observer whether a fruit had or had not been formed. When the bags were removed a careful study of the inclosed fruits was made and the data recorded.

Results and Discussion.

Dewberries.—The self-sterility work with the dewberries began with the planting of the varieties in the spring of 1908, and was finally completed in 1915, thus retaining the plants under observation for a sufficient number of years to warrant conclusions.

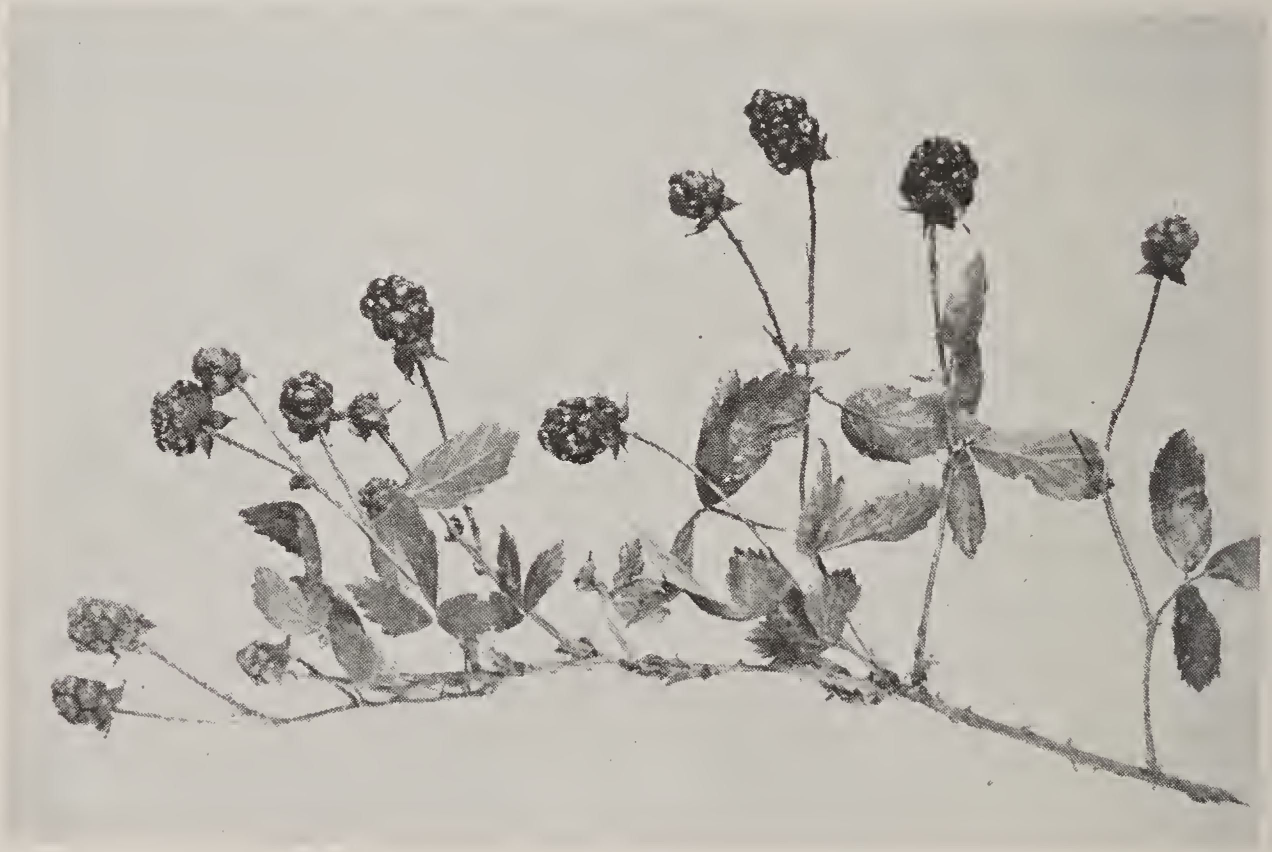

Fig. 2.—A fruiting branch of Manatee (dewberry.)

The results of the self-sterility test are set forth in the following table:

TABLE No. 1

DEWBERRIES.

Variety	Species	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Austin	Villosus	75	74	1	0
Chestnut	Trivialis	55	0	3	52
Cox	Hybrid	38	34	1	3
Ruth	Hybrid	27	26	1	0
Grandee	Trivialis	31	0	10	1
Limekiln	Trivialis	37	0	0	37
Lucretia	Villosus	30	28	2	0
Haupt	Hybrid	30	0	2	28
Manatee	Trivialis	71	0	20	51
Munroe	Trivialis	32	0	0	32
Premo	Villosus	56	0	0	56
Elijah, No. 2	Trivialis	23	0	0	23
Rogers	Trivialis	44	1	8	36
San Jacinto	Trivialis	58	0	1	57
White	Trivialis	59	0	1	58

By means of the above table we can readily group the dewberries and the hybrids (those grown as dewberries) into two well defined classes, namely, those that are self-fertile and those that generally are self-sterile.

The imperfect fruits listed with the self-fertile varieties will need no explanation, other than that untoward conditions frequently prevent the realization of an entire crop of perfect berries. But the imperfect berries listed with the otherwise self-sterile varieties need a few words of explanation. In the first place, the imperfect fruits, viewed from the point of commercial value, are negligible, for none of them were composed of more than eight druplets and most of them averaged less than four per berry. Furthermore, of those imperfect fruits produced by self-fertile varieties there were relatively many in each bag, while of those produced by the self-sterile varieties there were relatively few, not more than one fruit in the bag in most cases.

In the case of the Rogers variety, one bag produced one perfectly well formed and fully developed fruit. Besides this, eight bags with very small nubbins were also found. This well developed fruit undoubtedly was the result of the failure of the operator to remove a bloom which had already been fertilized and had dropped its petals. This fruit was produced in the year 1909, when twelve other bags produced only two imperfect fruits. This variety was again tested in 1910 and subsequently again in 1911. Of thirty-two bags recovered, no perfect fruits and only six very imperfect ones were discovered. We can thus safely disregard this one perfect fruit; but the imperfect ones of this and of other generally self-sterile varieties must still be accounted for. These imperfect fruits are not the result of errors in bagging, nor are they the result of defective bags, for examination disclosed no perforations through which insects might have gained access to the flowers within.

These fruits, then, are the result either of self-fertilization, parthenogenesis, or of parthenocarpy.

In order to determine the real cause of the development of the imperfect fruits, three varieties, which in the self-sterility test showed the greatest development of fruits, were selected in the spring of 1915. Of the variety Manatee, thirty-four flower buds were carefully emasculated, and immediately covered with a bag so as to prevent the access of any foreign pollen. Of Rogers and Grandee, thirty buds each were selected, emasculated and carefully covered.

The prevention of self-pollination of flowers determines whether fruit production is the result of a sexual union or whether it is the result of parthenogenesis or of parthenocarpy. As a check on this work, fourteen flower buds of White and ten each of Rogers and Munroe were covered when the buds showed their pink unexpanded petals. These buds not only were not emasculated, but also when the flowers opened were carefully hand pollinated with pollen of the same variety. To offset any injury that might result from the process of emasculation, five buds of these same varieties, White, Rogers, and Munroe, were carefully emasculated and later cross-pollinated with the following varieties: White with Rogers, Rogers with White, and Munroe with Chestnut.

The results of the experiment were as follows:

Table No. 2

Manatee	34 buds, emasculated and bagged	No fruits set.
Rogers	30 buds, emasculated and bagged	No fruits set.
Grandee	30 buds, emasculated and bagged	No fruits set.
White	14 buds, not emasculated and pollinated	6 nubbins, 8 no fruits.
Rogers	10 buds, not emasculated and pollinated	6 nubbins, 4 no fruits.
Munroe	10 buds, not emasculated and pollinated	1 nubbin, 9 no fruits.
White	4 buds, emasculated and crossed	4 good fruits.
Rogers	3 buds, emasculated and crossed	No fruits.
Munroe	3 buds, emasculated and crossed	3 good fruits.

From the above table we note that not one of the flower buds that were emasculated and not pollinated showed any evidence of fruit formation. This fact becomes interesting in that it at once eliminates the two points under consideration, viz., parthenogenesis and parthenocarpy. Hence we are led to believe that the small nubbins of berries that we found in the bags to which no foreign pollen has been admitted are the result of a sexual union of elements from the same flower. In short, some few ovules in these otherwise self-sterile varieties of dewberries will under certain conditions accept pollen from the same flower or from flowers of the same variety.

Of the flowers that were allowed pollen from the same flower and flowers of the same variety we find that, in the case of White, out of fourteen flowers inclosed, six produced fruit composed of a few druplets, and eight remained absolutely unaffected. The number of druplets that were produced by the flowers varied from one to five. Of the ten flowers of Rogers, six developed a few druplets and four developed none; while of the ten flowers of Munroe, only one flower developed a few druplets and nine absolutely refused the pollen.

That the injury done to flowers in the emasculation process, if carefully done, is negligible and does not affect the fruit formation is seen in the last part of the table where fruit buds of White were emasculated and crossed with pollen from the variety Rogers. Each of the four flowers that were emasculated and then cross-pollinated set and developed a normal good-sized berry. The three buds of Munroe that were treated in similar manner and then cross-pollinated with pollen from the variety of Chestnut also developed berries, normal in every respect. The three buds of Rogers that were emasculated and crossed with pollen from White produced no fruits. This result at first glance would indicate a positive reaction to emasculation injury, but a careful examination of the flower remains indicated that the trouble lay with the pollen rather than with the treated flower.

All these results seem to point toward the fact that a few individual pistils of flowers of these otherwise self-sterile varieties will accept some pollen from the same flower in order to effect fertilization. With these self-sterile varieties, this phenomenon seems to be the sole remaining sexual means of perpetuation of the species in case of isolation.

With this explanation as to the cause of imperfect fruits, we get a better understanding of the real significance of the data in Table No. 1.

The varieties of dewberries then can be grouped into self-fertile and practically self-sterile classes, which are as follows: as self-fertile, we list the varieties, Austin, Cox, Ruth, and Lucretia; as self-sterile, Chestnut, Grandee, Limekiln, Haupt, Manatee, Munroe, Premo, Elijah No. 2, Rogers, San Jacinto, and White.

If now we turn to the column of species, we shall discover that all of the varieties that are self-sterile, with only two exceptions, fall into the species *Rubus trivialis.* It will be noticed that this species contains no self-fertile varieties, and this is a good indication that the species itself if self-sterile. The two self-sterile varieties that are not classified with this species are Haupt (a hybrid) and Premo, the only self-sterile variety of the species *Rubus villosus* that we are growing.

Of the self-fertile varieties, Cox and Ruth are hybrids, and Austin and Lucretia belong to the species *Rubus villosus.*

Growers of dewberries might well take more than a passing notice of this fact of sterility in dewberries, and make ample provision for cross-pollination of varieties to insure a bountiful crop of fruit.

Blackberries.—The self-sterility work with the blackberries began in the spring of 1910 and was continued through three successive seasons, ending with the year 1913. The tabulated results give a pretty clear idea as to which varieties are self-fertile and which are self-sterile.

TABLE NO. 3

BLACKBERRIES.

Variety	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Blowers	41	38	3	0
Dallas	39	32	6	1
E. Cluster	34	33	1	0
E. Harvest	39	39	0	0
Eldorado	32	32	0	0
Illinois	31	30	1	0
Kenoyer	21	15	2	4
King	31	30	1	0
McDonald (hybrid)	45	0	0	45
Mersereau	31	31	0	0
Minnewaski	31	29	2	0
Rathbun (hybrid)	181	41	85	55
Snyder	30	28	0	2
Sorsby (hybrid)	28	0	0	28
Spalding (hybrid)	40	0	0	40
Wilson (hybrid)	41	40	0	1

Upon examination of the tabulated results, obtained under the same identical conditions of control as in the case of the dewberries, namely, the absolute exclusion of all foreign pollen from the bagged clusters, we notice that nearly all of the varieties are self-fertile, that one is imperfectly self-fertile, and that three are absolutely self-sterile.

Among the self-sterile varieties are Spalding, Sorsby, and McDonald; all three of which are hybrids between blackberries and dewberries. The imperfectly self-fertile variety, Rathbun, we also find to be a hybrid. All the rest of the varieties that are mentioned above are true blackberries and are self-fertile.

It may be said by way of explanation that in the above table those bags of blackberries that are listed as containing imperfect fruits differ essentially from similarly listed bags in the case of the dewberries in Table No. 1. The difference consists in the fact that in the case of the former the bags contained whole clusters of fruits which, although imperfect, were oftentimes large enough to be utilized in the harvesting and marketing of a crop. In the case of the dewberries, however, the bags contained fruits which, in number, averaged less than 10 per cent of the total number of flowers inclosed, and whatever fruit was in evidence was composed of only a few (one to eight) druplets.

Even from the commercial standpoint, that variety which produced large numbers of imperfect fruits, as recorded in Table No. 3, cannot be classified with those which produced no fruit whatever, and therefore must be classified as being only imperfectly self-fertile.

By an examination of the records of the hybrids in Table No. 1, and in Table No. 2, we notice the interesting fact that among them fertility ranges all the way from absolute self-sterility, as in the case of McDonald, Sorsby, Spalding, and Haupt, through partial sterility, as in the case of Rathbun, up to complete self-fertility, as is found in the varieties of Cox, Ruth, and Wilson.

Sterility, from the evidence at hand, apparently occurs only in dewberries and their hybrids. Its cause, therefore, must be studied with the aid of dewberry and hybrid material. Blackberry varieties will henceforth in this bulletin be considered only in their relation as pollinators for the berry plantation.

THE PROBABLE CAUSE OF STERILITY.

Having determined the fact that some of our varieties of blackberry-dewberry and dewberry-blackberry hybrids, and some of our true dewberry varieties, are self-sterile, we shall now proceed to investigate the cause or the causes that might be responsible for this phenomenon of sterility.

THEORIES ADVANCED.

The investigations as to the causes of sterility will proceed along eight lines, or theories, which may be advanced as an explanation of this phenomenon. These eight theories may be stated as follows:

1. The factor of the origin of the varieties.
2. The structure of the flower, and disease (Double Blossom).
3. The daily blooming period of varieties.
4. The amount of pollen produced by the flower.
5. The factors of environment.
6. Sterility due to hybridism.
7. The percentage of defective pollen grains produced.
8. Natural antipathy between the pistils and the pollen of the same variety.

EXPERIMENTAL EVIDENCE AND DISCUSSION.

Origin of Varieties.—From our results secured on the self-sterility and the self-fertility of varieties of dewberries, the fact becomes quite clear that the ancestral species of our cultivated varieties of dewberries fall into two well defined groups, namely, those that are self-sterile and those that generally are self fertile. The tabulated data in Table No. 1 reveals the fact that all of the varieties that are pure lineal descendants of *Rubus trivialis,* and those varieties in which trivialis blood predominates, are self-sterile, while those varieties that come from *Rubus villosus* generally are self-fertile. Of this last named species, two varieties, Premo and Rathbun, prove to be exceptions under our observation. Premo exhibits absolute self-sterility, while Rathbun (a hybrid) is only partially self-fertile.

However, with only two varieties of *Rubus villosus* proving to be positively self-fertile, and one decidedly self-sterile, it was deemed expedient to test the species at large, that is, the wild species, before making any generalizations.

Rubus villosus is indigenous to our soil and climate, and the vines are to be found growing profusely and abundantly in and about our fields and woods. Accordingly, in the spring of 1915 twenty individual wild vines were marked, and on April 20th five clusters of flower buds on each of the vines were covered with cloth and paper bags.

If the species be self-sterile, we would find no fruits in the bags during the fruiting season; if the species be self-fertile, then we should expect to see a crop of berries in each of the undisturbed bags; if the species be composed of both self-fertile and self-sterile vines, then we should expect to get varying results. The following table shows the results of this test:

Table No. 4

Number of Vine	Species	Number of Bags Recovered	Number of Fruits	Number Without Fruits
No. 1	Villosus	4	4	0
No. 2	Villosus	4	2	2
No. 3	Villosus	4	3	1
No. 4	Villosus	1	0	1
No. 5	Villosus	5	0	5
No. 6	Villosus	5	4	1
No. 7	Villosus	3	2	1
No. 8	Villosus	5	4	1
No. 9	Villosus	4	2	2
No. 10	Villosus	9	9	0
No. 11	Villosus	10	10	0
No. 12	Villosus	9	9	0
No. 13	Villosus	5	5	0
No. 14	Villosus	7	6	1
No. 15	Villosus	11	11	0
No. 16	Villosus	14	3	11
No. 17	Villosus	4	4	0
No. 18	Villosus	5	4	1
No. 19	Villosus	5	5	0
No. 20	Villosus	5	5	0

From the tabulated results, the fact stands out very clearly that the species *Rubus villosus* at large is quite self-fertile. From this it is evident that the case of the variety Premo is simply an exception to the general rule, and requires special investigation.

It will be noticed that vines Nos. 4 and 5 record absolute self-sterility; but this sterility is undoubtedly due to the fact that the flower buds of these vines were far too small when they were inclosed. The same may be said about most if not all of the other buds that proved to be self-sterile. The proper time to inclose the buds is when the pink shows well on the expanding petals, and about one or two days before the bud may be expected to open.

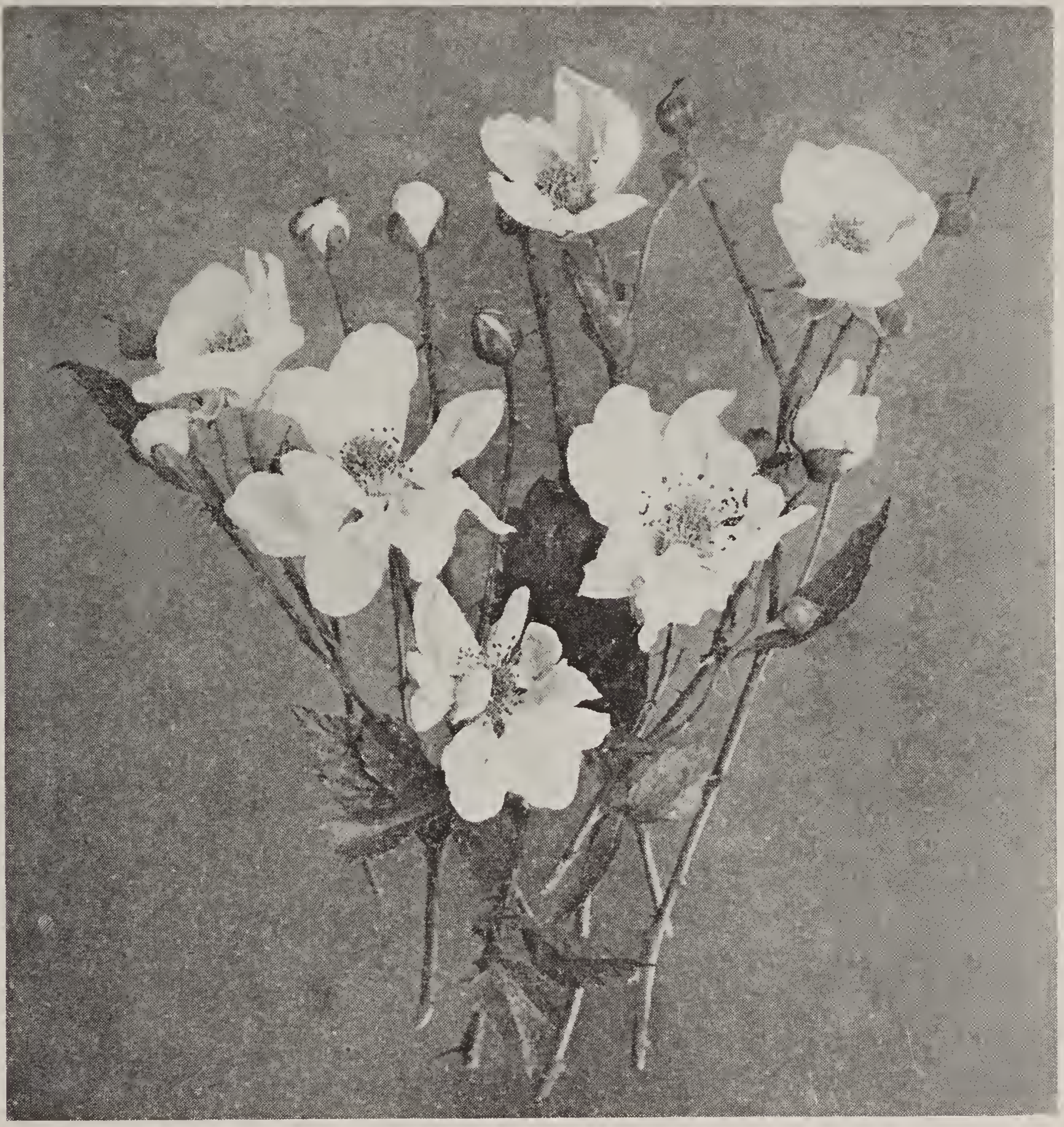

Fig. 3.—Flowers of Manatee (dewberry) showing good cases of petalody.

Knowing, then, that the parental species of our cultivated varieties of dewberries are either self-fertile or self-sterile, we should anticipate finding similar characteristics respectively in the daughter vines, and with few exceptions such is the case.

The Structure of the Flower and Disease.—Petalody in the genus Rubus is by no means an unusual phenomenon, but when it occurs to such an extent and to such a high degree of development that it may endanger the normal functions of the essential organs of the flower, then it becomes a vital factor in fruit production. This numerical increase in number of petals has developed to an unusual and to a very marked degree in the case of the variety Manatee.

Each of the plants of this variety was examined as to petalization, and each was found to produce blooms with both a normal and an abnormal number of petals. As the normal number of petals for the genus Rubus is five, any flower with more petals was considered petaliferous. The actual number of petals ranged all the way from five to twelve and fifteen. This condition of petalody is not peculiar to the variety Manatee, except in degree. Many other varieties are more or less affected, and notable among these are Chestnut and Elijah No. 2. Some of the flowers of Manatee are often so double as to resemble a small pink rose. In some years this abnormal condition of the bloom is much more pronounced than in others.

When many flowers of Manatee are bagged and allowed to be self-pollinated, we observe that frequently among them some will develop and bring to maturity a small number of druplets. This phenomenon has been observed in such other varieties as Chestnut, Grandee, Haupt, Rogers, and to a very limited extent in San Jacinto and in White.

When Manatee is cross-pollinated with other varieties of dewberries, fruits will develop, but the berries are very rarely perfect and well formed.

The reason that these berries seldom develop normally may be attributed to climatic or to soil conditions, for in Florida, where Manatee originated, the vines are said to produce an abundance of well formed fruits.

In order to ascertain whether Manatee is sterile because the extra number of petals really hindered pollen from reaching the stigmas of the pistils, five flower buds were bagged and pollen from Manatee flowers was artificially applied. Later, upon examination of these inclosed flowers, it was discovered that no fruits had set. The complete record of results follows:

TABLE No. 5

Number of Bags	Number of Flowers	Number of Perfect Fruits	Number of Nubbins	Number Sterile
No. 1	1	0	0	1
No. 2	1	0	0	1
No. 3	1	0	0	1
No. 4	1	0	0	1
No. 5	1	0	0	1

The results in the above table indicate that the excessive number of petals in the dewberry flowers does not necessarily constitute a mechanical obstruction to the process of pollination, but that Manatee is self-sterile, notwithstanding the fact that its flowers frequently have an excessive number of petals.

If we carefully examine the flowers of our cultivated varieties of dewberries and hybrid blackberries we notice that two varieties, viz., Premo and Rathbun, show irregularities in the formation of their stamens. The flower buds of Premo are different from those of most other varieties of dewberries and blackberries in that the pistils rapidly elongate and protrude from the flower buds several days before the petals expand, and before the stamens mature. This apparently is a provision for securing cross-pollination.

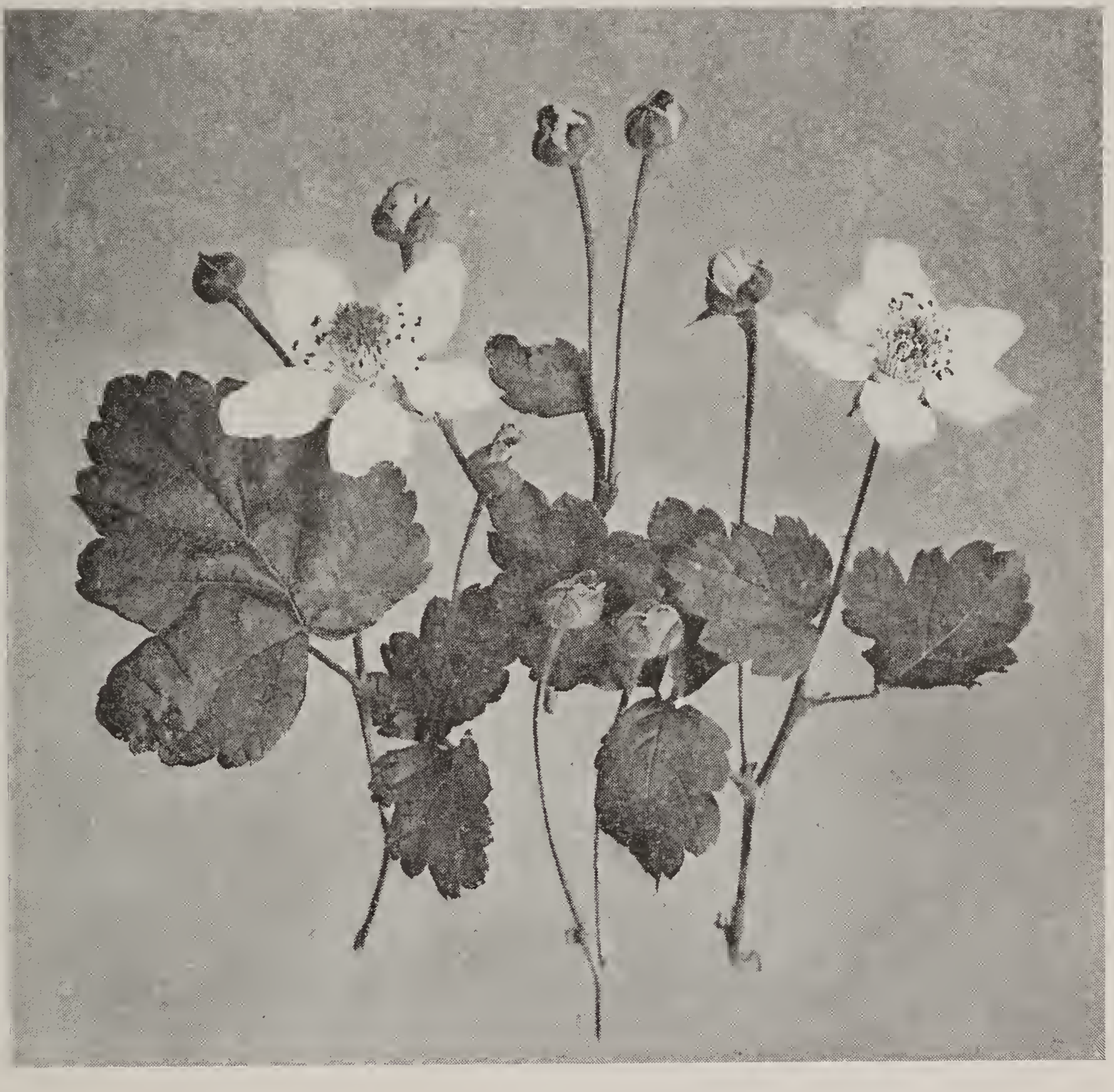

FIG. 4.—Flower clusters of Premo (dewberry), showing how the pistils protrude from the bursting flower buds.

Also, very often the stamens of the flowers are defective. Many of them never develop beyond mere rudimentary organs, some partly develop, others have their filaments dwarfed, and still others develop normal filaments but with anther sacks that are diseased and which liberate only defective or aborted pollen. The remaining stamens apparently produce normal pollen, but fruit will not set when the flowers are self-pollinated.

The flower of Rathbun is very similar to that of Premo except that the pistils do not protrude from the flower bud. When Rathbun flowers are self-pollinated we usually get some fruit development, and this fruit may range all the way from almost perfect to no fruit at all.

In regard to the question of self-sterility of varieties of dewberries, however, the fact still remains that in many other varieties with healthy normal stamens, complete self-sterility exists. Hence, another solution of the question of sterility must be sought.

Petalody in normal plants must not be confused in any way with Double Blossom (34th Ann. Rept. N. C. Agr. Exp. Sta., 1912, by Reimer and Detjen ~~and De~~; Agr. Exp. Sta. Bul. No. 93, by M. T. Cook), which is a disease that is caused by a parasitic fungus, *Fusarium rubi* (Winter).

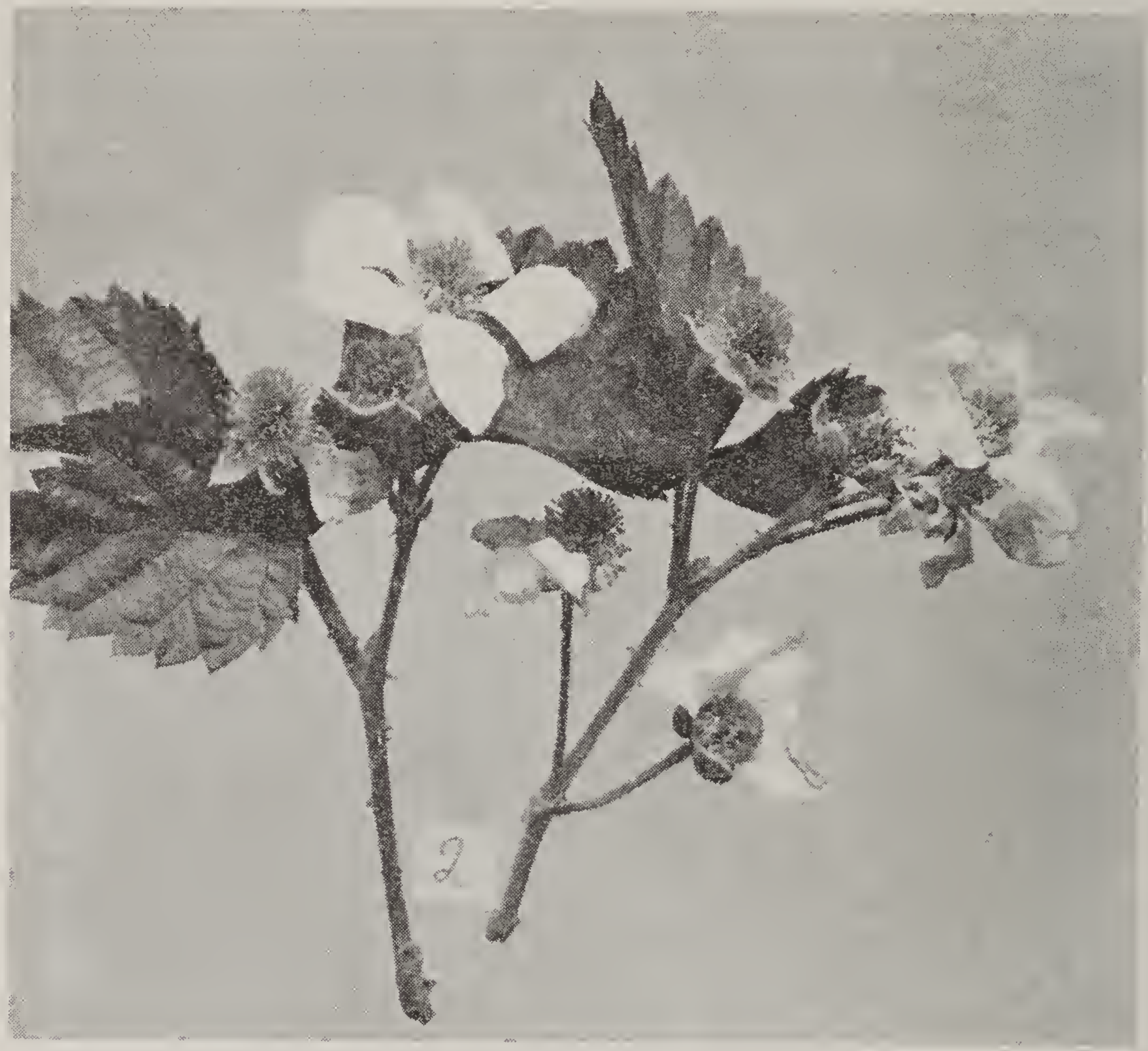

Fig. 5.—Flowers of Rathbun, (blackberry-dewberry hybrid), showing very much weakened and reduced stamens.

This fungus is frequently the cause of the development of unusually large numbers of petals in the flowers of some varieties, notably, Lucretia and Wilson. In fact, some of the affected blooms quite resemble a small white double rose.

The real difference between a petaliferous bloom of a normal plant and a petaliferous bloom of one that is affected with *Fusarium rubi* is revealed in the production of fruit. Petaliferous flowers on otherwise normal plants, when cross-pollinated with self-fertile varieties, very frequently set normal berries, while those petaliferous blooms which are the direct result of the action of fusarium very seldom if ever set fruit. The reason for this can be attributed to the destruction by the fungus of the essential organs in the flowers.

Sometimes, as in the case of the variety Manatee when cross-pollinated with pollen from self-sterile varieties, only nubbins are produced; however, this phenomenon is explained elsewhere in this bulletin, and will not be discussed at this point.

"Double Blossom" is not always revealed by the phenomenon of petalization. Many flowers that are apparently normal never set any fruit. In such cases only the sexual organs have been affected by fusarium, and consequently no fruit was produced. Careful examination of the flowers of all of our varieties that are affected with sterility, however, revealed only a very few traces of the disease.

The Daily Blooming Period.—In searching for the underlying cause of sterility in dewberries, it was deemed advisable to investigate the daily blooming period, and the relative time of dehiscence of the anther sacks. Flowers of *Rubus villosus* were observed opening at different times, some in the morning hours, some at noon, and still others in the afternoon. In fact, flowers in all stages of opening could be observed during all times of the day, depending, of course, upon the conditions of the weather.

Flowers of the different varieties of *Rubus trivialis* were observed to behave in a very similar fashion to those of *R. villosus;* hence the daily blooming periods of the two species, in this respect, are quite similar.

The anthers also were investigated as to the time of their dehiscence. It was found that in neither case did all of the anthers dehisce at the same time. Anthers sometimes burst before the petals expand, but in the majority of cases dehiscence begins after the flower has fully opened. The outer cycle of stamens first begins to shed its pollen, and the other or inner cycles follow in the order of their maturity. Generally speaking, twelve to twenty four hours elapse before the last anther in the flowers has burst.

Because of this continuous shedding, a scarcity of pollen cannot be held responsible for the nonsetting of fruits, because any insect visiting such flowers cannot fail to become coated all over with the powdery element and transfer the same to other flowers.

Both species of dewberries were carefully observed in this respect, and as no difference in their behavior was found, we were forced to conclude that the daily blooming period and the time of the shedding of pollen has no effect on the general question of sterility.

The Amount of Pollen Produced.—By comparing the flowers of the self-fertile varieties with those of the self-sterile varieties, we observe at a glance that, with a few exceptions, the former produce far more pollen than the latter. This fact at once raises the question, Does the small amount of pollen that is produced by some varieties account for the nonsetting of fruit?

In Table No. 6 is found the answer to this question. Pollen carefully gathered from the self-sterile varieties was actually applied by hand to the pistils of flowers of the same varieties, and no fruit was obtained. Therefore, the insufficiency of pollen production does not account for the absolute sterility of any variety of dewberries or of their hybrids.

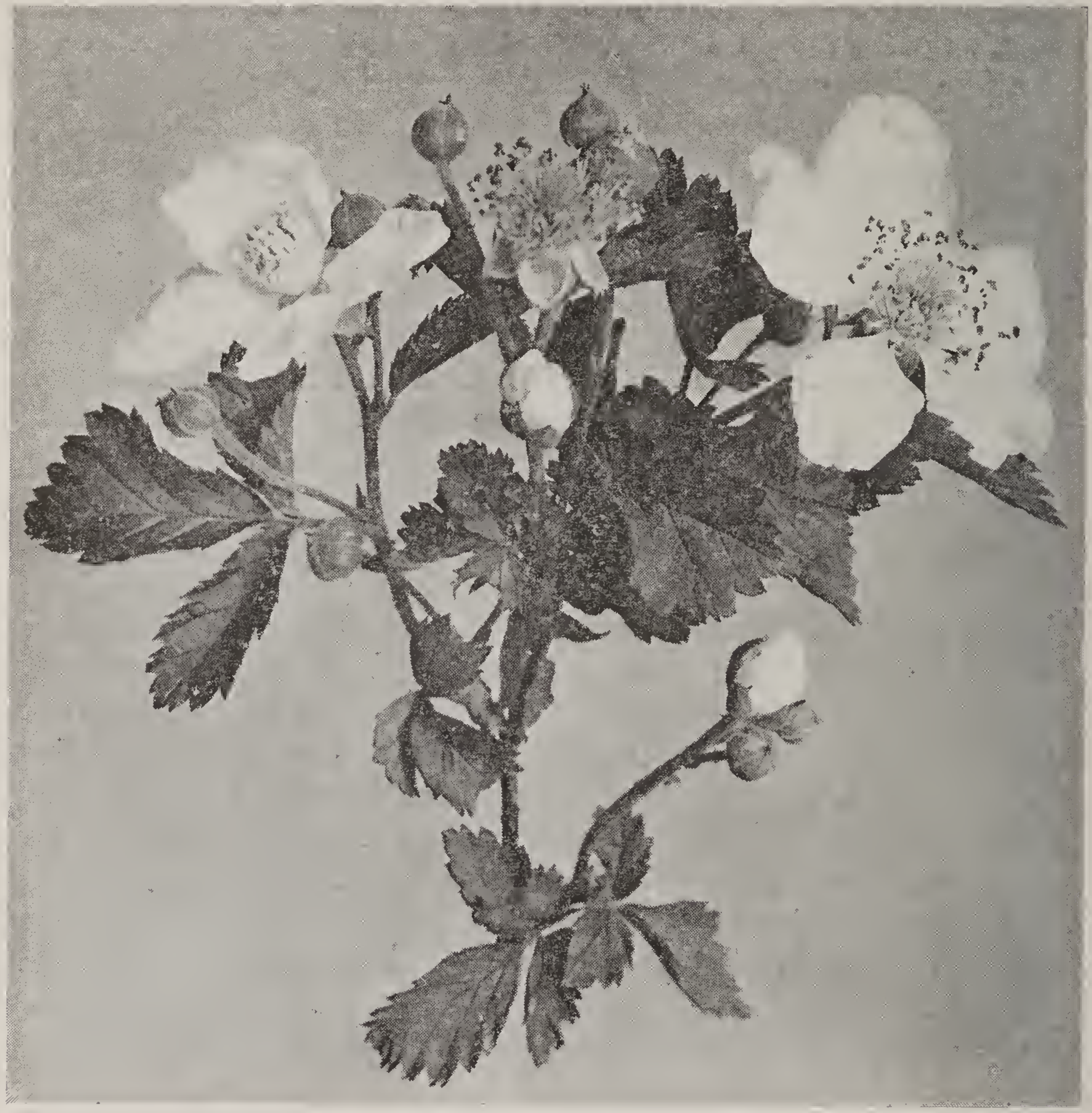

FIG. 6.—Flowers of Lucretia (dewberry), showing well developed stamens.

However, in the growing of berry crops for commercial purposes we must bear in mind that the factor of pollen production is an important item. Insufficiency of pollen under these conditions may be the real cause of a crop failure, even although it will not account for the self-sterility of the variety. Because not enough of pollen is produced to satisfy the requirements of the pistils in all of the flowers of the whole field, the resultant crop is not only reduced in size, but also in quality, for the individual berries have suffered because a certain percentage of its ovules did not receive the proper amount of pollen that is required for complete fertilization. Hence a large number of nubbins are produced instead of the well developed berries. The real cause of sterility, however, has not yet been reached.

Sterility Due to Environmental Conditions.—It is a fact that trees and plants which are generally self-fertile, under normal conditions, will produce an abundance of fruit, but which when subjected to abnormal conditions, such as a superfluity of moisture, an abnormal amount of nitrogen in the soil, late spring frosts, etc., will forego the production of fruit. In order to forestall any influences that might find their origin in the environs of the plants under our observation, the test plants in our experimental field were laid out in the following manner:

A square field, having approximately an area of two and one-half acres, was divided into two nearly equal parts, the division line extending from west to east. The northern half was devoted entirely to blackberries and blackberry-dewberry hybrids, and the southern half to dewberries and dewberry blackberry hybrids. Each half of the field was further subdivided into equal sized plats sufficiently large to accommodate three rows of each of the varieties with thirty plants to the row. The plants and the rows lie in a north and south direction. The distances between the plants in the rows, the rows from one another, and the spaces between the separate plants were made equal and uniformly at five feet. The whole field was laid off on the square system. Thus, the whole collection of test plats has the appearance of a regular fruit plantation. No especial care was exercised in the selection of varieties which were to occupy the successive plats of the plantation; however, it so happened, as was later discovered, that the self-fertile and the self-sterile varieties were pretty well mingled.

The square system of planting made possible the uniform cultivation of the individual plants in both directions, and made impossible unconscious differences in the treatment of the individual plats.

The soil of this berry plantation is a sandy loam underlaid with a clay subsoil and is as nearly uniform as it was possible to secure. Fertilizers were applied semiannually to the plantation as a whole, the phosphates and potash predominating in the spring application and the nitrogen element predominating in the summer application.

The cultivation of the individual plats consisted in the cultivation of the plantation as a whole; clean culture in the spring and summer, and a cover crop of rye or of cowpeas in the fall and winter. Thus the soil treatment accorded to one plat was accorded to all, and therefore the environment of one variety became, as nearly as was possible to make it, the environment of each and all other varieties.

If, then, the environment be the cause of the sterility of the different varieties, we should anticipate either sterility in all of the varieties or no sterility in any of them. It might be contended, however, that the conditions to which all of these varieties were subjected might be more detrimental to some species or varieties than to others, and that for this reason varieties might behave differently. Allowing due credit for this fact, we nevertheless find that under normal conditions, and with varieties interplanted for cross-pollination, we get normal crops of fruit from all with the exception of Manatee. This fact is sufficient evidence that soil and soil-fertility factors must be separated and eliminated from the real causes that underlie the phenomenon of sterility of varieties in dewberries and dewberry hybrids.

Another factor of environment, namely, that of late spring frosts, must here be considered, because in this case the different varieties are not similarly affected. Some varieties of dewberries and hybrids are more subsceptible to cold than are some others.

Late spring frosts may destroy a berry crop in two different ways: first, by killing outright the succulent growth of vines that begin activity of growth during the early warm spells of late winter; and second, by the injury of the blooms of early flowering varieties. The crop of blooms for the season being destroyed, but very little fruit from such varieties can be expected during the following season.

Although all of the varieties of dewberries that have their origin in *Rubus trivialis* (and also the four hybrid varieties, Haupt, Sorsby, Spalding, and McDonald, which, from evidence derived from Table No. 1, prove to be self-~~fertile~~ sterile) belong to this group of early growers, and although it frequently happens that in this locality, as well as elsewhere, these varieties frequently have their crop of fruit considerably diminished by late spring frosts, the fact yet remains that during normal years these same varieties bring forth a bountiful supply of fruits. Thus, late spring frosts cannot be regarded as the cause of the general sterility of dewberries and their hybrid varieties.

Sterility Due to Hybridism.—That the mating of two widely separated species of plants or of animals frequently produces sterility in the offspring is a recognized fact. As an example, Dr. Peter Wylie in his report on the breeding of grapes wrote as follows: "We can impregnate the foreign (*Vitis vinifera*) with pollen from the Scruppernong, producing thereby only male (staminate) plants and imperfect hermaphrodite or pistillate plants, which bear no fruit." Again, all of Rogers' hybrids which are the offspring of native species of grapes crossed with pollen from *Vitis vinifera* are with only one exception self-sterile.

Any investigation as to the sterility of any variety of plants would be incomplete if it omitted altogether this important factor of ancestry.

By investigating the botanical characters of our cultivated varieties of dewberries we arrive at certain definite conclusions: First, that most of our cultivated varieties of dewberries, as near as we can ascertain, are direct lineal descendants from native species, and that but few are hybrids. Second, that generally the direct descendants of these native species retain the same relationship to the question of fertility exhibited by the parental species. An exception to this rule is found in the case of the variety Premo, which presumably is a direct descendant from the self-fertile species *Rubus villosus*. Third, that true hybrids between self-fertile species of Rubus (examples of which are the varieties Cox, Ruth, and Wilson) may retain complete self-fertility, but sometimes only partial self-fertility, as in the case of Rathbun. Fourth, that true hybrids of Rubus species with self-sterile species may be self-sterile, examples of which are Haupt, Spalding, Sorsby, and possibly McDonald.

These hybrids are not self-sterile, however, because of the fact that they are of hybrid origin, but, rather, because sterility was imparted to them directly by one of their parents, presumably some variety of *Rubus trivialis*.

Since some of the varieties of true dewberries which show no hybrid origin are utterly incapable of setting fruit by themselves, we conclude that the true cause for the sterility of the dewberries and their hybrids must be sought elsewhere.

Amount of Defective Pollen (Miscroscopical Test)

Table No. 6

PERCENTAGE OF NORMAL POLLEN GRAINS.

Variety	Species	Count Number 1	Count Number 2	Count Number 3
		Per Cent.	*Per Cent.*	*Per Cent.*
Austin	R. villosus	92.1	95.9	95.6
Chestnut	R. trivialis	73.5	77.9	83.7
Cox	Hybrid	78.6	76.8	83.7
Ruth	Hybrid		74.6	82.4
Grandee	R. trivialis	41.2	69.6	51.1
Limekiln	R. trivialis	93.4	92.0	91.3
Lucretia	R. villosus		92.7	95.8
Haupt	Hybrid	38.2	77.4	82.9
Manatee	R. trivialis	95.9	39.7	36.8
Munroe	R. trivialis	96.5	96.3	96.5
Premo	R. villosus		94.8	94.5
Elijah, No. 2	R. trivialis	78.0	96.3	93.2
Rogers	R. trivialis	94.5	91.9	92.5
San Jacinto	R. trivialis	68.9	79.6	91.7
White	R. trivialis	95.2	96.4	92.8
Spalding	Hybrid			56.4
Rathbun	Hybrid			57.5
McDonald	Hybrid			59.5
Sorsby	Hybrid			76.3
Wilson	Hybrid			53.2

The method used to secure the data in the above table was as follows: ten normal flowers, selected quite at random from different plants of the same variety, were used to supply the representative samples of pollen. The pollen from the ten flowers was shaken into a glass vial, thoroughly mixed by mechanical means, and then subjected to a miscroscopical examination. This examination consisted in counting and recording of the total number of apparently perfect and the total number of defective pollen grains that were found in ten separate fields under the microscope. From these figures the percentages of good and of defective pollen grains were calculated.

This method of procedure was repeated for each variety, and the condition of its pollen determined. It must be stated that pollen grains which appeared normal regardless of actual viability were classed as good grains, and only small, hollow, and shriveled grains were counted as defective. With some varieties this distinction becomes somewhat difficult because of the production of a great many angular grains which closely resemble the defective ones.

From the tables we learn some interesting facts: first, that the self-fertile ~~sterile~~ varieties of *Rubus villosus* produce a comparatively high (over 90%) percentage of normal pollen grains, and that Premo, the only lineal descendant grown here which does not produce such a quantity of normal pollen, is self-sterile; second, that the other self-sterile varieties, all of which, with the exception of the hybrids, are representative varieties of *Rubus trivialis,* vary considerably in the amount of defective pollen that they produce. Such varieties as Limekiln, Munroe, Rogers, and White produce a very small percentage of defective pollen, less than 8 per cent. In this respect they correspond very favorably with those varieties that are of Villosus origin and which are self-fertile. Other varieties of this same species, such as Chestnut, Manatee, and San Jacinto, show a very much larger per cent of defective pollen. With the exception of Manatee, these varieties produce approximately from 50 to 80 per cent of normal pollen. Manatee falls far below this class in that it sometimes produces as high as sixty and three-tenths (60.3) per cent and sometimes as high as ninety-four and one-tenth (94.1) per cent of defective pollen. All of these varieties are self-sterile. Cox and Ruth, two self-fertile varieties of hybrid origin, while perfectly self-fertile, produce as high as approximately twenty-two and three-tenths (22.3) per cent and twenty-five and four-tenths (25.4) per cent of defective pollen grains; while Haupt, a hybrid, which also produces an equally large amount of perfect pollen, is self-sterile.

From these results it becomes quite evident that the quantity or the number of defective pollen grains in the flowers of our self-sterile varieties of dewberries and hybrids plays no fundamental role in the cause of self-sterility of such varieties. The production of a comparatively high or a comparatively low percentage of defective pollen grains, however, becomes of vital importance to the commercial fruit grower in the selection of pollinators for the berry plantation. For, other conditions being equal, the greater the per cent of pollen produced, the greater are the chances for perfect cross-pollination and a "bumper" crop. The subject of the commercial importance of varieties which habitually produce a high per cent of perfect pollen will be discussed later under the subject of pollinators for the plantation.

Germination Test of Pollen.—Having discovered that self-sterile varieties of dewberries produce an abundance and in some cases, as high a percentage of morphologically normal pollen grains as any of those varieties that are self-fertile, the question of the viability of these apparently normal grains becomes of prime importance.

Pollen was gathered from all of the varieties, and subjected to a germination test in the laboratory by means of "hanging-drop" slides and germination solutions. The culture medium, as was discovered, might consist of either weak sugar solutions of varying strength, tap water, or even distilled water. Ordinary tap water was as good as any, and less troublesome to secure.

All of the examined slides disclosed the fact that the pollen grains which morphologicallly appeared normal were capable of a vigorous germination and growth, and that the self-sterility of varieties of dewberries is not caused by morphological defectiveness or a lack of viability in the pollen grains. Sterility has its seat in a more remote cause and requires further investigation.

Natural Antipathy Between Pistils and Pollen from the Same Variety.—Because self-sterile varieties of dewberries and their hybrids will, under normal conditions for cross-pollination, set an abundance of fruit, the fact is quite patent that the morphology of the pistils (stigma, style, and ovary) is quite normal, and apparently offers no explanation of the phenomenon of sterility. From the foregoing recorded results in regard to the viability of pollen from self-sterile varieties, and also from the good fruit crops secured under ordinary field conditions, we naturally draw the conclusion that the viability of the pollen grains is not responsible for the sterility of the variety. All of the essential organs of the flowers under certain conditions seem to function normally, and yet this phenomenon, self-sterility, does exist.

Whether in the case of self-pollination the pollen functions normally and the pistil behaves abnormally, or *vice versa,* or whether both organs refuse to act, has not been determined. At any rate, the antipathy between the pistil and pollen of the same variety seems to be the immediate cause for the failure of fruit setting, and therefore of self-sterility.

What this rather vague term, natural antipathy, really signifies—whether it is due to a toxic substance located in the pollen grain in the stigmatic secretions, style, or the ovules—remains yet to be discovered.

Viable pollen grains from a self-sterile variety, although ineffective on the pistils of flowers of the same variety, will bring about perfect fertilization when placed on the stigmas of another variety; and it matters little whether this second variety be self-fertile or self-sterile, of the same species or of another species (*Rubus villosus*).

The following table shows the results of extensive cross-pollination tests:

DEWBERRIES AND HYBRIDS.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1911—					
White	San Jacinto	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	6	6	0	0
	Limekiln	4	4	0	0
	Rogers	5	5	0	0
	Manatee	2	1	1	0
Limekiln	White	5	5	0	0
	San Jacinto	5	5	0	0
	Chestnut	5	5	0	0
	Manatee	5	3	1	1
	Rogers	5	5	0	0
	Munroe	5	5	0	0
Munroe	White	5	5	0	0
	San Jacinto	5	5	0	0
	Chestnut	4	4	0	0
	Limekiln	4	4	0	0
	Rogers	3	3	0	0
	Manatee	5	4	1	0
San Jacinto	White	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	4	4	0	0
	Limekiln	5	5	0	0
	Rogers	4	4	0	0
	Manatee	5	5	0	0
Chestnut	White	5	5	0	0
	San Jacinto	4	4	0	0
	Munroe	4	4	0	0
	Limekiln	5	5	0	0
	Rogers	5	5	0	0
	Manatee	4	4	0	0
Rogers	White	4	4	0	0
	San Jacinto	4	4	0	0
	Munroe	5	5	0	0
	Chestnut	5	5	0	0
	Limekiln	5	5	0	0
	Manatee	3	3	0	0
Manatee	White	5	2	0	3
	San Jacinto	5	0	0	5
	Rogers	4	0	0	4
	Limekiln	3	0	1	2
	Munroe	5	0	1	4
	Chestnut	4	1	0	3
1912—					
Manatee	White	5	1	0	4
	San Jacinto	5	0	0	5
	Rogers	3	0	0	3
	Limekiln	4	0	0	4
	Munroe	5	0	0	5
	Chestnut	4	0	1	3
	Haupt	5	0	2	3
	Grandee	5	0	2	3
	Lucretia	8	8	0	0
	Cox	5	5	0	0
	Ruth	4	4	0	0

DEWBERRIES AND HYBRIDS—CONTINUED.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
1915—					
San Jacinto	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Grandee	1	1	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Manatee	2	0	2	0
	Check	1	0	1	0
Rogers	Chestnut	1	1	0	0
	Lucretia	2	2	0	0
	Elijah, No. 2	2	1	0	1
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Manatee	2	0	2	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	2	0
Elijah, No. 2	Lucretia	2	2	0	0
	White	2	2	0	0
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Premo	2	0	2	0
	Munrce	2	2	0	0
	Manatee	2	0	2	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	0	2
Manatee	Lucretia	1	1	0	0
	White	2	0	0	2
	San Jacinto	2	0	0	2
	Rogers	1	0	0	1
	Elijah, No. 2	2	0	1	1
	Premo	2	0	2	0
	Munrce	2	0	0	2
	Haupt	1	1	0	0
	Limekiln	2	0	0	2
	Grandee	2	0	1	1
	Ruth	2	2	0	0
	Cox	2	1	1	0
	Chestnut	2	0	1	1
	Austin	2	1	1	0
	Check	2	0	0	2
Munrce	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	1	1	0
	Grandee	2	1	0	1
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Check	2	0	0	2
	Manatee	2	0	2	0

DEWBERRIES AND HYBRIDS—Continued.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Haupt	White	2	2	0	0
	San Jacinto	2	1	0	1
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	2	0
	Lucretia	2	2	0	0
	Limekiln	2	2	0	0
	Ruth	2	1	0	1
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	4	4	0	0
	Check	2	0	0	2
White	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Lucretia	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0
	Manatee	2	0	2	0
	Check	1	0	0	1
Grandee	Lucretia	2	2	0	0
	White	2	1	1	0
	San Jacinto	2	1	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	1	1
	Haupt	2	0	2	0
	Limekiln	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	1	1	0	0
	Austin	2	2	0	0
	Check	3	0	2	1
Lucretia	White	2	0	1	1
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	1	1	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	0	2	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Manatee	4	0	3	1
	Check	2	0	0	2
Chestnut	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Haupt	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Austin	2	2	0	0

DEWBERRIES AND HYBRIDS—CONTINUED.

Variety	Cross-pollinator	Number of Bags Recovered	Bags with Perfect Fruits	Bags with Imperfect Fruits	Bags with No Fruits
Chestnut	Manatee	2	0	1	1
	Check	2	0	0	2
Austin	Lucretia	2	2	0	0
	White	2	1	1	0
	San Jacinto	2	0	2	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	2	0	0
	Munroe	2	2	0	0
	Manatee	2	0	1	1
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	0	1	1
	Ruth	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Check	4	0	0	4
Cox	Lucretia	2	2	0	0
	White	2	2	0	0
	San Jacinto	2	2	0	0
	Rogers	2	1	0	1
	Elijah, No. 2	2	2	0	0
	Premo	2	0	0	2
	Munroe	2	2	0	0
	Manatee	2	0	0	2
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	3	0	0	3
Premo	Lucretia	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Manatee	2	1	1	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Ruth	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	5	0	0	5
Ruth	Lucretia	2	2	0	0
	White	3	3	0	0
	San Jacinto	2	2	0	0
	Rogers	2	2	0	0
	Elijah, No. 2	2	2	0	0
	Premo	2	1	0	0
	Munroe	2	1	1	0
	Manatee	2	0	2	0
	Haupt	2	2	0	0
	Limekiln	2	2	0	0
	Grandee	2	2	0	0
	Cox	2	2	0	0
	Chestnut	2	2	0	0
	Austin	2	2	0	0
	Check	5	0	0	5
Limekiln	Manatee	2	0	1	1

From a study of the above tables we come to the following conclusions: first, that the pollen from the self-fertile varieties of *Rubus villosus* can fertilize the flowers of other self-fertile varieties of the same species; second, that the pollen from self-fertile varieties of *Rubus villosus* can fertilize the flowers of self-~~fertile~~ sterile varieties of the same species, and also, with the exception of the variety Manatee, those of the self-sterile species, *Rubus trivialis;* third, that the pollen from the self-~~fertile~~ sterile variety Premo can fertilize the self-~~sterile~~ fertile varieties of the same species, and, with the exception of Manatee, the self-~~fertile~~ sterile varieties of *Rubus trivialis;* fourth, that the self-sterile varieties of *Rubus trivialis* can fertilize all varieties of *Rubus villosus* and, with the variety Manatee excepted, the self-sterile varieties of *Rubus trivialis* and their hybrids; fifth, that the pollen from a self-sterile variety cannot fertilize the flowers of the same variety.

Consequently, the very interesting fact becomes evident that self-fertile varieties are not the only ones that can be used successfully as pollinators in a berry plantation, but that so far as viability of the pollen and fertilization is concerned, we can also use the recognized self sterile varieties. This fact, with the exception of Manatee, holds true, even though all of the varieties that are to be pollinated are self-sterile.

The variety Manatee presents a very unique case, and requires some words of explanation. From the information gained in Table No. 1, we learn that Manatee is practically a self-sterile variety. Frequently, however, under certain conditions of self-pollination, one to several druplets will be produced and will ripen. This condition, as has previously been stated, appears to be the result of self-fertilization. Other varieties of *Rubus trivialis* frequently behave similarly.

Manatee, when crossed with other varieties, behaves variously: generally speaking, it will not set much, if any, fruit when crossed with pollen from the self-sterile varieties of *Rubus trivialis.* When crossed with pollen from the self-fertile varieties of *Rubus villosus* some fruits will develop; but with us, Manatee growing in a mixed plantation never has set a paying crop of berries. As a pollinator for other varieties, therefore, Manatee is worthless, because the percentage of defective pollen produced by its flowers is so great that in a large berry plantation a dearth of viable pollen would be the result.

As has already been mentioned, the pollen of Manatee seems not to be very acceptable to flowers of other varieties of *Rubus trivialis,* for while in some years fairly good fruit was obtained in the hybridizing tests, yet in other seasons the resultant fruit crop was exceedingly poor, and in some cases no fruit at all was obtained. Neither is it very acceptable to varieties of *Rubus villosus.* Lucretia, Austin, Premo, and the self-fertile hybrids, Cox and Ruth, when pollinated with Manatee, show varying results. Of the varieties mentioned, Ruth seems to be able to use Manatee pollen to the best advantage, for the resultant fruit seems quite normal in all external appearances. To sum it up, the variety Manatee has nothing to recommend it as a fruit producer, and still less as a general pollinator for other varieties.

POLLINATORS FOR THE BERRY PLANTATION

Although most of our important varieties of dewberries and blackberries are self-fertile, the crops might be considerably improved by the judicious selection of good pollinators. Pollinators not only serve to improve a crop, but, with many varieties, they are an actual necessity for the production of berries. Thus, all of the varieties that spring from the species *Rubus trivialis* need a pollinator in order to set a crop of fruit. Other varieties of dewberries are similarly affected, and the absence, in some cases, of a suitable pollinator practically means the total loss of a fruit crop.

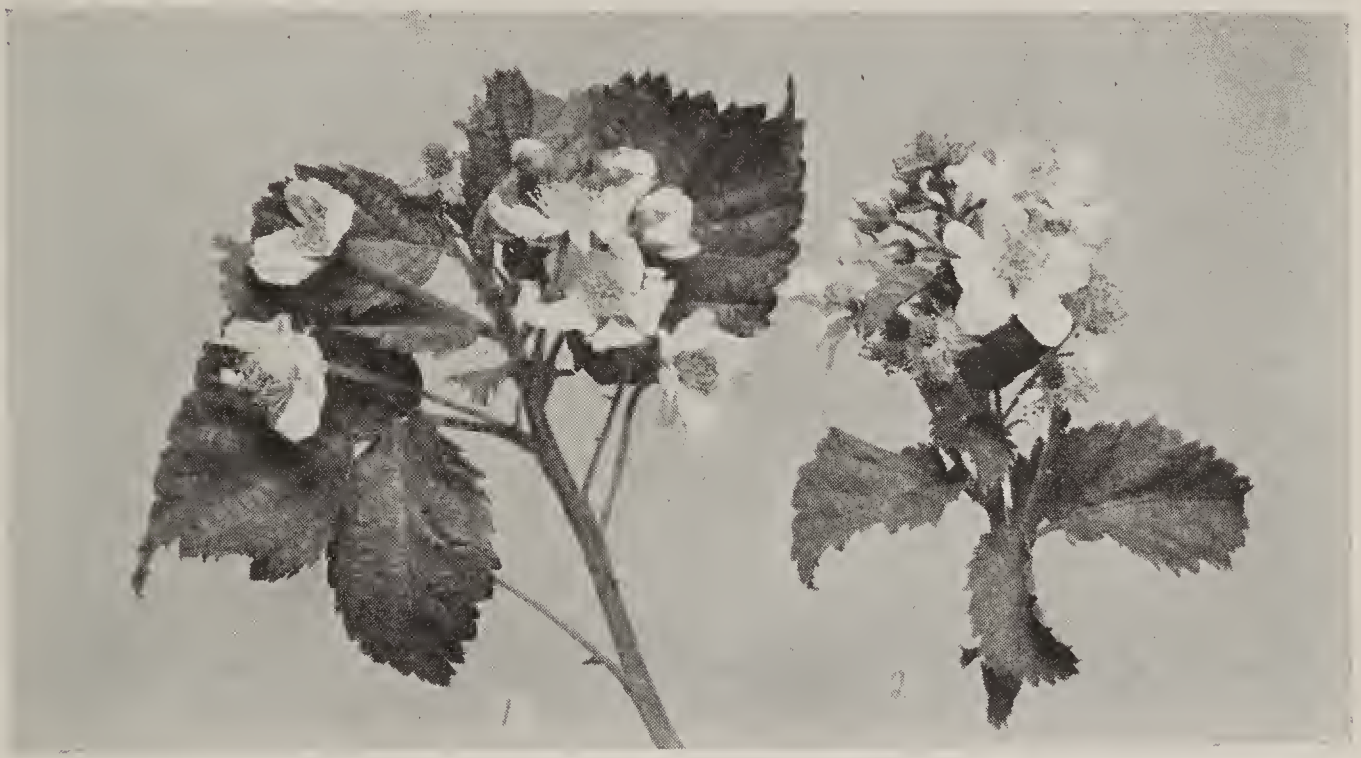

Fig. 7.—Flower clusters of Snyder and King (blackberries), showing ample pollen production.

Requirements of a Good Pollinator.—The requirements of a good pollinator are the following: first, self-fertility; second, a blooming period which is coincident with that of the variety to be pollinated; third, the production of an abundance of good viable pollen.

That self-fertile varieties are most desirable for pollinators becomes evident from the fact that during unfavorable weather conditions in the blooming season the flowers of such varieties are still able to set an abundance of fruit with the aid of their own pollen—they need not wait for insects to carry the pollen to them. On the other hand, with varieties not perfectly self-fertile, any condition which affects the activity of insects during the blooming season also affects the setting of fruit more or less seriously.

Dewberry and blackberry flowers differ somewhat from flowers in general as regards to pollen production. Instead of all of the anthers bursting when the bloom opens, the anthers of the outer cycles alone dehisce first, followed gradually by the other cycles as they come to maturity. Flowers of this sort are not completely damaged by one rainstorm, because only the loose pollen is washed away, and when the weather clears up the anthers of the inner cycles mature and are ready to supply all the pollen needed by its own flower and the flowers that might be in the vicinity.

Table No. 8

BLOOMING PERIODS OF DEWBERRIES AND BLACKBERRIES.

DEWBERRIES.

Variety	1910 First Bloom	1911 First Bloom	1915 First Bloom	1915 Last Bloom
Austin	Apr. 5	Apr. 17	Apr. 20	May 14
Chestnut	Apr. 4	Apr. 20	Apr. 19	May 24
Cox	Apr. 5	Apr. 20	Apr. 20	May 14
Ruth	Apr. 5	Apr. 21	Apr. 24	May 21
Grandee	Mar. 31	Apr. 20	Apr. 19	May 14
Limekiln	Mar. 31	Apr. 20	Apr. 20	May 20
Lucretia	Apr. 5	Apr. 21	Apr. 24	May 22
Haupt		Apr. 28	Apr. 20	May 19
Manatee	Apr. 4	Apr. 14	Apr. 19	May 19
Munroe	Apr. 4	Apr. 17	Apr. 19	May 20
Premo	Apr. 5	Apr. 17	Apr. 24	May 16
Elijah, No. 2	Apr. —	Apr. 17	Apr. 15	May 19
Rogers	Apr. 4	Apr. 14	Apr. 12	May 14
San Jacinto	Apr. 4	Apr. 17	Apr. 15	May 14
White	Mar. 31	Apr. 17	Apr. 14	May 15
BLACKBERRIES.				
Blowers	May 1	Apr. 24	Apr. 29	May 21
Dallas	Apr. 28	Apr. 24	Apr. 25	May 20
E. Cluster	Apr. 22	May 1		
E. Harvest	May 1	Apr. 24	Apr. 26	May 19
Eldorado	May 3		Apr. 30	May 22
Illinois	May 1		Apr. 30	May 21
Kenover	Apr. 29	Apr. 29	Apr. 26	May 19
King	May 3	Apr. 24	Apr. 29	May 22
McDonald	Apr. 8	Apr. 17	Apr. 20	May 13
Mersereau	Apr. 22	May 3	Apr. 29	May 22
Minnewaski	Apr. 22	May 1	Apr. 30	May 22
Rathbun		May 1	Apr. 28	May 21
Snyder	May 3	Apr. 23	Apr. 29	May 22
Sorsby	Apr. 25	Apr. 22	Apr. 24	May 18
Spalding	Apr. 27	Apr. 20	Apr. 24	May 18
Wilson	Apr. 19	Apr. 23	Apr. 26	May 21

For best results, the blooming periods of the different varieties should be coincident so far as possible. This is especially true when only a very few varieties are under consideration. The earliest and the last blooms require a pollinator equally as potent as do those blooms from which the main crop is expected. In the consideration of several to many varieties, which are intended to cover the whole fruiting season, it is necessary only to have the blooming period of some varieties overlap at all times, so that at no time in the booming season should we find but one variety in flower.

From the above table we learn that all of the earliest blooming dewberries belong to the species *Rubus trivialis,* which are self-sterile. Consequently, in selecting pollinators we must select such varieties as bloom at the same time, regardless of the fact that they are self-sterile.

The blooming period of dewberries lasts about four weeks. Straggling blooms may be found at all times during the fruiting season, but they may be safely disregarded, for there are not enough of them to warrant the time wasted in the gathering of the resultant fruits.

The blooming period for the blackberries seems to be a little shorter than that for the dewberries. Stragglers are here found mostly among the blackberry-dewberry hybrids, while the true blackberries seem to have a more definite blooming period.

Self-fertile vs. Self-sterile Varieties to be Used as Pollinators for the Berry Plantation.—From evidence disclosed elsewhere in this bulletin, it becomes evident that the requirements of pollinators need not necessarily hinge on the question of self-fertility of varieties, for we found that with one exception a self-sterile variety will readily cross with other self-sterile varieties; but the fact must be kept in mind that self-sterile varieties generally possess in a less degree the qualifications for a good pollinator; that self-fertile varieties will set fruit in bad as well as in good blooming seasons, and that the flowers of self-fertile varieties, whose blooming periods do not overlap, will nevertheless produce an abundance of perfect fruit, while those of the self-sterile varieties may not. For these reasons the self-fertile varieties of dewberries and hybrids that are grown either as dewberries or as blackberries ought to be given preference whenever possible in the selection of pollinators for the berry plantation.

Comparisons of Fruits from Self-fertilized and Cross-fertilized Flowers.—Leaving out of consideration the question of parthenocarpy, we find that in fruits generally those flowers that are cross-pollinated usually produce larger and better fruits than those that are self-pollinated. Whether this factor is of sufficient importance in the production of dewberries and of blackberries is a question worthy of consideration.

In order to investigate the probable effect of cross-pollination over that of self-pollination with varieties of dewberries and blackberries and their hybrids, two lots of flowers from each of two representative varieties of each type were selected. Lucretia and Austin were chosen to represent the dewberries; Early Harvest and Snyder, the blackberries; and Wilson and Cox, the hybrids. Each lot of the different varieties consisted of large branches with flowers clusters in as nearly the same stage of maturity as it was possible to find. All of these branches were covered alike with cloth bags; the first lot, in order to prevent cross-pollination; and the second or check lot, in order to offset the effects of the covering in the first lot. The only difference in the resultant fruits must, then, be due to the origin of the pollen.

The flower clusters were covered, when possible, before any of the flower buds had opened, and such as had opened were carefully removed, so as to forestall any results due to activities of insects in their daily search for pollen and nectar. The bags covering the clusters of self-pollinated flowers were never lifted until comparisons of the inclosed fruits were made, while those bags which covered the cross-pollinated

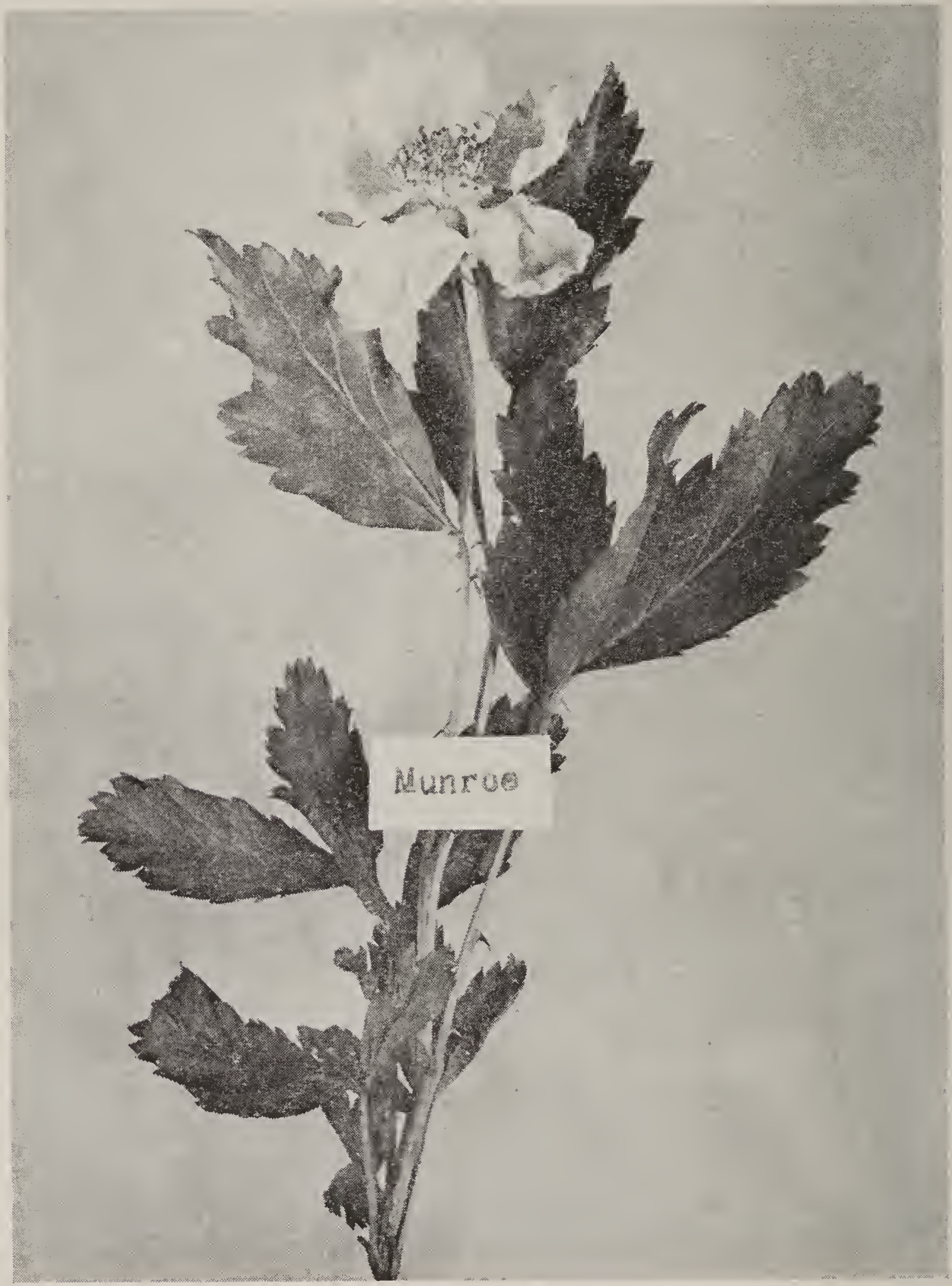

FIG. 8.—A flower cluster of Munroe (dewberry), showing an abundance of strong, healthy stamens produced by a self-sterile variety of Rubus trivialis.

flowers were lifted every day during the blooming season and the inclosed flowers crossed with pollen from other varieties until the last bloom was past the stage of receptivity. After this, these bags were also allowed to remain untouched until the inclosed fruits were ready for comparison.

Results and Discussion.—Of the dewberries, all of the bags were recovered. Both branches of each variety that was self-pollinated differed in no respect from similar branches that had been carefully crossed; nor did they differ from normal branches of fruit that were found in the open and had been left to insect pollination. The individual fruits were much alike in size, shape, color, and general condition.

With the hybrid vines, Wilson and Cox, similar results were obtained. No deleterious effect of selfing was noticed. In the case of the blackberries, Snyder behaved in similar manner. Early Harvest produced two branches of good fruits and two branches of poor fruits; but it so happened that the "selfed" lot, like the "crossed" lot, produced one good branch and also one poor one. In this instance the poor development of fruit cannot be attributed to self-fertilization, but must be ascribed to some other unknown agent that attacked the branches of both plants alike.

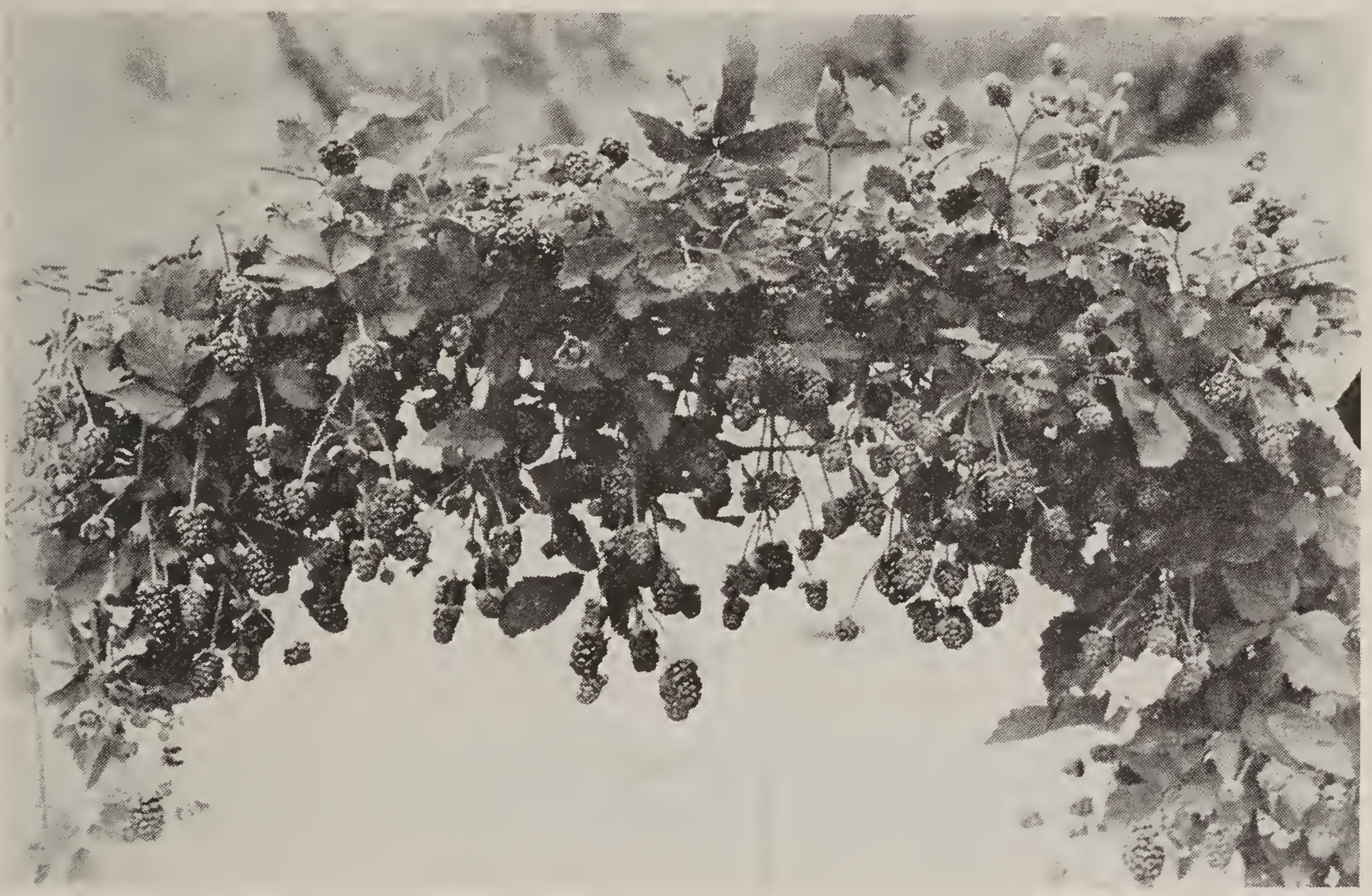

Fig. 9.—Lucretia dewberry (Rubus villosus). A good crop of dewberries produced by a self-fertile vine.

It must be remembered, however, that in this experiment only known self-fertile varieties from each type were selected. Had we included partially self-sterile varieties or wholly self-sterile varieties, the results would have been most striking and to the contrary.

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